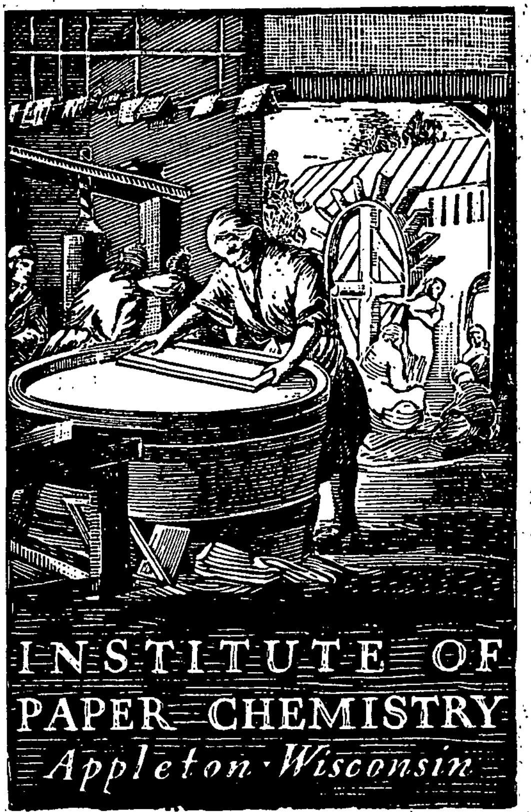

IMPROVED BONDING STRENGTH OF GROUNDWOOD FURNISHES: EXPLORATORY PROGRAM WITH ASPEN STONE GROUNDWOOD

Project 2948

Report One

A Progress Report

to

MEMBERS OF GROUP PROJECT 2948

May 10, 1972

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Appleton Papers, Inc. — Locks Mill

Blandin Paper Company

Crown Zellerbach Corporation

Great Northern Paper Company

Kimberly-Clark Corporation

St. Regis Paper Company

Southwest Forest Industries

U.S. Plywood-Champion Papers Inc.

The Upson Company

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THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

IMPROVED BONDING STRENGTH OF GROUNDWOOD FURNISHES

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SUMMARY

The problem of improved groundwood bonding was approached by reviewing the fundamental aspects of fiber bonding in regard to the needs and characteristics of the pulp and to the economic boundaries imposed by the relative market values of groundwood and chemical pulps. The preparation of chemical derivatives of groundwood was considered to be one way the pulp surface could be altered to increase swelling and conformability to improve bonding strength.

The need to retain the shape and form of a papermaking pulp requires two-phase reactions between the pulp and the chemical reagents. This means that the particle surface area governs the reactivity and that the fines component of the pulp would be most susceptible to modification. An evaluation of the relative bonding abilities of fines from a bleached kraft pulp and from a hardwood stone groundwood showed that both the coarse and fine fractions of the groundwood could benefit from treatments to improve bonding. Further, that it was reasonable to proceed with chemical treatments even if the major effect was likely to be upon the fine fraction.

Groundwood slurries were treated with sodium hydroxide and carbon disulfide to form a groundwood xanthate derivative according to procedures developed elsewhere for cornstarch. After oxidation with iodine to produce disulfide cross-links and form the xanthide derivative, greatly improved strength values were obtained for handsheets made from 50/50 blends of kraft and treated groundwood pulps. However, it was found that even stronger handsheets were

obtained when the groundwood was subjected only to the strong alkali treatment which was needed to make the xanthate derivative. It was shown that the improvement was not due to prolonged mechanical agitation. By agreement with representatives of the cooperating firms, the focus of the program was shifted to follow the lead shown in the data for the effect of sodium hydroxide by itself.

The economic factors affecting groundwood pulps indicated that a rapid, more or less continuous process or treatment was needed. For this reason a continuous steam injector, or jet cooker, was assembled to evaluate reported bonding improvements with heat alone and to observe the effect of a wide range of temperatures upon the alkaline treatments. Heating neutral streams of 2% aspen groundwood over a range of 150 to 310°F. had a small, constant beneficial effect upon handsheet tensile strength (8 to 10%) but none upon bursting strength. Lindberg and MacLaurin found both tensile and burst were improved by longer term heating of southern pine stone groundwood.

About 4 to 7% greater breaking length was noted for raising the processing temperature from 190 to 230°F. with 5 parts NaOH per 100 parts pulp but none was seen between 230 and 270°F. The effect of the sodium hydroxide concentration was greater than the temperature effects over the range of 190 to 270° with 0 to 10% NaOH on the pulp. Substantial improvements in bonding strength (e.g., 50-70% higher tensile) were obtained with 5 and 10% NaOH along with a darkening of the pulp.

The addition of 5% hydrogen peroxide along with 5 and 10% NaOH not only prevented color degradation but also bleached the pulp. The brightness of 20/80 and 50/50 kraft/groundwood handsheets was increased 9 to 10 points over the untreated controls and 11 to 18 points over the alkali controls. The breaking length of the 20/80 treated handsheets exceeded that of the 50/50 untreated control while the burst was nearly equivalent. The brightness value for the 20/80 handsheets from the treated pulp was nearly 5 points greater than the value from the 50/50 untreated blend.

The data presented in this report establish that it is possible simultaneously to bleach and to improve the bonding of an aspen stone groundwood in a rapid, continuous process.

INTRODUCTION

Project 2948 was established at The Institute of Paper Chemistry in response to the interest of several manufacturers in developing methods to improve bonding in groundwood furnishes. This is Report One and describes the initial, exploratory experiments seeking ways to achieve the goals of the project. Part of the experimental work presented here was discussed during a meeting with representatives of the cooperating firms on October 22, 1970. The remainder describes work done on the program which was outlined during that meeting. This report will be followed very shortly by a final report covering more recent cycles of experiments.

Several points of agreement were reached during the October, 1970 project meeting. The first studies would be limited to a single source of groundwood, evaluation would be done by testing mixed stock handsheets, and Instron tensile strength tests, including the tensile energy absorption values, would be the primary criteria for judging bonding. It was also agreed, that groundwood pulps which already had acceptable papermaking properties would be used and that the mechanical preparation of the pulp would not be part of the program.

One of the major limitations preventing greater use of groundwood is the low strength of the paper made from such mixed stock furnishes. In general, physical strength properties such as burst, tensile, and tear resistance decrease as the proportion of groundwood increases in the mixed furnish. Casey (1) does state that a small amount of groundwood (up to 10 to 20%) in a long-fibered chemical pulp will generally increase the bursting strength slightly without lowering tear resistance. He speculates that this is due to the groundwood filling in between the longer fibers of the chemical pulp.

The lower strength of the groundwood furnishes has been attributed to a reduced capacity for forming fiber-to-fiber bonds. This is in addition to the effects of the shorter fiber or particle length. If the bonding ability of groundwood pulps could be improved, more groundwood could be used in place of expensive chemical pulps. The result should be significant reductions in cost while maintaining product standards.

BACKGROUND

As the name implies, groundwood pulps are prepared by mechanical attrition of woody tissues. Segments of a tree trunk may be forced against a wet, revolving grindstone or suspensions of wood chips, and occasionally sawdust, maybe crushed, sheared, and abraded in refiners. In some instances, the woody material may be softened by steam or by chemical impregnation before being ground or passed through the refiner.

In contrast with the chemical pulps from the kraft and sulfite processes, groundwood pulps are not a collection of individual, chemically extracted but morphologically intact plant cells. Rather, such pulps are an array of fiber bundles and fragments. The lignin content of the pulp is essentially that of the wood and all but the more soluble cellular components are retained. Coloring matter, waxes, resins, and other materials present in the wood are also present in the pulp and have bearing upon the brightness and aging properties of the pulp. In this way, the species of wood used has another effect upon pulp quality in addition to the obvious ones due to its fiber dimensions and the density of the wood.

Since so little of the woody tissue is extracted, groundwood pulps represent from 90 to 95% of the weight of the raw material. In contrast, the yield of chemical pulps is about 50% but may be somewhat higher or lower depending upon the processing conditions selected.

Wood species commonly used for groundwood pulp include softwoods such as spruce, fir, and pine, as well as hardwoods such as poplar, birch, and maple. Traditionally, spruce has been the standard for comparing the quality of groundwoods from different species. However, experience has led to improved processing and a better understanding of properties so that hardwoods such as poplar may be preferred in some products. Availability, rather than desirability often governs the selection of wood to be used in groundwood production.

Processing details, such as the angle of the wood fiber to the grinding surface, the size of the grit in the grindstone, the pattern cut into the stone face, the freshness of that pattern, the pressure of the wood onto the stone surface, surface speed of the stone, the volume of water applied to the stone, temperature of the water and many other factors enter into making groundwood. Thus, a rather large number of variables are capable of being set to different values to control the process. In spite of this, specific statements of criteria for judging groundwood quality are not in abundance in the open literature (2). Judging from the information that is available, it appears that the primary quality judgment is in regard to the particle size distribution, especially the amount and size of the coarsest fraction. Roughly, the smoother the printing surface required, the smaller the size of the coarsest fraction must be. The more the groundwood fragments resemble fibers, the better the groundwood quality. Larger bundles and splinters are unacceptable and wood flour is practically useless.

The size of the coarsest fraction can be regulated by selection of grit size, cutting angle, and other grinding variables along with screening to remove the coarser fragments until an acceptable range is obtained. Since reduction of the size of the largest particles increases the amount of the smallest particles (40 to 60% by weight through a 150-mesh screen) (1), freeness values can be used as control points. Other criteria include visual appearance, feel, strength values of handsheets and assessment of fiber length distribution. These criteria are then related to the properties of a paper product and the acceptance of that product by the customer.

The factors which affect the adhesion of fibers in the paper structure were reviewed sometime ago by Swanson (3). He pointed out that secondary molecular forces play a dominant role in bonding similar and dissimilar surfaces together. These secondary forces, or Van der Waals forces, may be classed into three main types: orientation forces which exist between rigid dipolar molecules, induction forces which result from the action of dipolar molecules upon a polarizable nonpolar molecule, and dispersion forces which exist between all molecules. Of these three, the orientation effect is of major importance with substances possessing a relatively high dipolar character such as the hydroxyl groups of the cellulose monomer units. The existence of these groups allows the sharing of a hydrogen atom between the hydroxyl oxygen atoms and oxygen.

Swanson (2) stresses the following:

1. Hydroxyl groups are strongly polar.
2. Papermaking pulp fibers have a multitude of such groups which are potentially capable of interaction by the orienting effect, by hydrogen bonding, as well as the dispersion effect.

3. The attractive forces mentioned above decrease with the inverse seventh power of the distance. Therefore, elements of the fiber surface which are to be bonded must approach one another very closely if these forces are to become effective. The distance of separation should be no more than a few Angstrom units.

4. Rigid, solid surfaces are very rough on a molecular scale and the real area of contact is very small when two such surfaces are brought together.

One of the major objectives in papermaking, thus, is to prepare fibers in such a form that an optimum amount of molecular contact can be obtained. This is one of the primary reasons for beating and refining pulps. During mechanical refining, the cellulose fibers swell considerably, the specific surface area of the fibers increases, and the fibers become more flexible as they become plasticized with water. In addition, the spirally oriented fibrillar structure of the cellulose fiber is gradually loosened and unraveled as the action of the beater scuffs and rubs the overlying surface. All of these factors lead to a greater ability of the surface to conform, span voids, and to increase the area of intimate molecular contact.

The fact that groundwood pulps do not respond to beating and refining like most of the chemical pulps is one of the reasons for this project. Lignin and other cellular cementing substances retained in the pulp inhibit swelling of the groundwood particles and prevent the loosening of fibrils from the cell walls and fragments of cell walls. The pulp elements do not become more flexible and conformable with increased refining to the same extent as the chemical pulps even though there may be a gradual reduction in particle size.

If improved groundwood bonding is to be achieved, it is obvious some other process is required to produce a surface which will be soft enough to conform to other fiber or particle surfaces to establish the molecular contact needed for the secondary attractive forces to be effective. Such a process could be chemical derivitization such as has been done with cotton linters (4-6). Reacting these almost pure cellulose fibers with ethylene oxide or ethylene chlorohydrin, to give low levels of hydroxyethyl ether groups on the pulp cellulose, materially improved the papermaking qualities of that raw material. Its effect is believed to be improved plasticization and conformability of the fibrous elements to improve contact in the bonding area (7).

Other possible treatments include selective absorption of suitable polymers onto the groundwood and exposure to strong swelling agents such as zinc chloride and calcium thiocyanate.

PROJECT DEVELOPMENT

The aims of this project as developed up to this point are to improve groundwood bonding by preparing cellulose derivatives which will increase the interaction of the pulp particles with water. This is expected to produce a more highly hydrated and conformable surface and thus to increase the bonded area in papers made from the treated pulps. It is necessary to consider not only the chemical modifications which would accomplish these changes but also the processing conditions which would be acceptable.

The most obvious requirement is that the expense of installation and operation must be more than compensated by economic gains somewhere else; for example, by being able to use more groundwood and less chemical pulp in a given product while maintaining the required properties.

Since chemical pulps cost about twice as much as groundwood pulps, the process must not double the cost of usable, treated groundwood. This leads to the recognition that the yield of treated pulp must be high. A fifty percent loss of pulp would in itself double the cost. Further, there is not enough room economically to consider treatments in nonaqueous systems (8). The cost of removing the pulp from existing processing systems, drying it and treating it with vapors or in nonaqueous solvents would very likely increase the cost of treatment beyond acceptable limits.

It would be desirable if aqueous suspensions of the groundwood could be treated at pumpable consistencies. Uniform and rapid blending of the pulp and chemical reagents would be more readily obtained with suspensions than by treating batches of crumbs from a wet-lap machine. Continuous operation could also be a possibility with pumpable suspensions which should lead to lower manpower requirements and a reduced inventory of pulp in process.

For the maximum level of control over the process and a minimum of down time, the treatment process should be as simple as possible. Effluents from the process, both liquid and vapor, must be amenable to treatment — preferably in existing systems.

Thus, it appears that the kind of process that would find the greatest probability of acceptance would be: a cheap, nonpolluting, simple, continuous, chemical treatment that produces a high yield of processed pulp from fluid slurries drawn from the groundwood manufacturing process. The problem now is to assess what chemical treatments will approach these criteria.

The proposal which led to the acceptance of this project indicated a strong interest for investigating xanthate derivatives of groundwood cellulose. There were several reasons for this interest.

Cellulose xanthate is made commercially by the simple expedient of blending crumbs of wet sodium hydroxide-treated wood fibers with carbon disulfide at or slightly above room temperature. The resulting sodium cellulose dithiocarbonate ester will dissolve in cold sodium hydroxide solutions to form viscose dopes which are very nearly true solutions. In the manufacture of regenerated cellulose films and fibers, the viscose solution is extruded as a film or as filaments into a coagulating bath. Further mild treatments with solutions of dilute acids and salts remove the cellulose-solubilizing xanthate groups so that the extruded forms become essentially pure cellulose. Viscose solutions have also been applied to paper products to impart wet strength following cellulose regeneration and drying (9).

The xanthate derivative of cellulose has two characteristics which have led to its commercial utility. It provides a way to solubilize cellulose and its chemical instability allows a rapid and comparatively simple way to reverse the solubilizing effect and regenerate insoluble cellulose. Our aim in considering the xanthate derivative of groundwood lies in using the solubilizing effect; that is, to enhance the interaction of groundwood and water. However, the degree to which this derivative or any other derivative is formed must be limited so that the pulp constituents will not become too soluble and be washed out of the papermaking process. One problem in this regard is the need to soak the pulp in strong solutions of sodium hydroxide before the carbon disulfide is introduced. Such treatment in itself could solubilize a significant portion of the groundwood.

Thus, in addition to the need for regulating the degree of substitution of the pulp xanthate, the extent of alkaline extraction must also be controlled.

Fortunately, cellulose and hemicellulose xanthates can be readily converted to insoluble forms. Consequently, pulp components which may become soluble during treatment by extraction should be converted to their xanthate derivatives more readily than the material remaining in the solid phase and thus be as susceptible to insolubilizing reactions as those fractions which became soluble by overreaction.

Chlorine, iodine, hypochlorous acid and some other oxidizing agents react with the dithiocarbonate ester substituents to bring about cross-linking to reduce the solubility of the polymers. This reaction is illustrated in Equation (1).

$$2\ \mathrm{RO\overset{S}{\overset{\|}{C}}{-}S^-} + I_2 \rightarrow \mathrm{RO\overset{S}{\overset{\|}{C}}{-}S{-}S{-}\overset{S}{\overset{\|}{C}}OR} + 2I^- \qquad (1)$$

Such disulfide cross-linked products have been called xanthides. Moreover, the treatment destroys the odor of hydrogen sulfide which is formed as a by-product of the xanthate process. Thus, it appears that the two major objections to considering xanthation as a possibility for groundwood strength enhancement, solubilization and odor, should be overcome by a single treatment with, for example, Cl_2 or HOCl. This could be the final step before the groundwood xanthide emerges from a closed processing unit. Processes for preparing starch xanthate and starch xanthide continuously in closed reactors have been developed on a pilot-plant scale (10,11). Thus, information is available to assist in designing a continuous process should it become desirable to produce groundwood xanthate and xanthide on a larger scale.

Regardless of what kind of groundwood derivative is to be made by chemical reaction, the product must remain in the form of a fibrous papermaking material. The shape of the treated particles should remain essentially unchanged. That is, swelling and flexibility may be increased but the particle has to stay in a recognizable form. This means that the chemical reaction must occur between two phases — solid-liquid or solid-gas. The reactivity of the solid phase thus is directly proportional to the area of surface exposed to the chemical reagents. This fact has particular bearing upon groundwood treatments in that about half of that pulp is an array of very small particles which have a much greater surface area per unit weight than the larger, coarser fractions. Thus, the groundwood fines, which comprise from 40 to 60% of the pulp when considering the fraction passing through the 150-mesh Bauer-McNett screen (1), represent the major portion of the pulp most susceptible to chemical modification. The question arises whether this is desirable or not. Chemical pulp fines are reputed to have significant bonding properties. However, Gavelin (2) does not indicate that groundwood fines are particularly valuable.

In this report, the bonding capabilities of groundwood fines is compared with fines from a bleached softwood kraft pulp. The evaluation was done before an attempt was made to produce the xanthate derivative to assess the probability of its harming, rather than improving, groundwood bonding. After determining that groundwood fines are not especially good bonding agents in respect to kraft fines, the initial studies of groundwood xanthide were carried out. These results were presented orally at the October, 1970 project meeting mentioned earlier. A decision was reached at that meeting to change the emphasis of the research program in light of these results which will be discussed more fully in a different section.

The reason for shifting the program direction was that groundwood control which was treated with sodium hydroxide alone and not with carbon disulfide produced stronger handsheets than the pulp exposed to both reagents.

It was concluded that sodium hydroxide treatments appeared to be the more desirable path to follow and that such treatments would be done in conjunction with an evaluation of the effect of heat alone since some earlier workers had found improved bonding with wet heat (12). It was pointed out that refiner groundwoods have latent strength properties depending upon the time of sampling in process. This effect has been described in the literature and procedures have been developed to allow for the "latency" property (13,14). It was not anticipated that "latency" would be a factor since a hardwood stone groundwood had been selected for study. However, the results were viewed keeping in mind the possibility of the effect occurring.

In any event, heating groundwood pulps had to be examined in view of the report in the literature and the simplicity of the treatment. For this purpose, a small, laboratory-size continuous steam injection jet cooker was constructed. Slurries of the hardwood groundwood in tap water, both with and without sodium hydroxide, were pumped through this cooker to cover a wide range of processing temperatures.

The value of treating groundwood pulps with alkali has been known for some time. Richter received a patent in 1931 (15) for treating softwood groundwood at 10% consistency in 4 to 10% sodium hydroxide (roughly 40 to 100% on the weight of the pulp). He states that the temperature must be below 70°C. (158°F.) and gives examples of room temperature treatments. Pretreatments with chlorine and bisulfite are cited but not claimed in the patent. The process required about one hour. Yields ranged from 70 to 85% of the original pulp with the pentosan content dropping from 10 to 14% down to 5 to 7%.

Foote and Parsons (16), in 1955, described their laboratory experiments and mill experience with hardwood groundwood treated with 3 to 10% sodium hydroxide (based on dry pulp). Retention times were on the order of 2 to 3 hours. These authors stress that washing is essential after the caustic treatment to avoid excessive bleach consumption. Opacity loss was reduced by blending in about 50% untreated groundwood pulp before bleaching in the normal manner. Brightness loss is said to be 1.2 to 3.7 per 1% sodium hydroxide (in the range of 3 to 10 g./100 g. pulp) and was accompanied by a gain of 4 to 5 in the Mullen test.

Neale, et al. (17) found, on eucalypt groundwood, that sodium and potassium hydroxide were equally effective on an equivalent basis for extracting coloring matter and improving brightness, bleachability, and strength properties. These alkalies were superior to calcium hydroxide, sodium carbonate, and ammonium hydroxide. The preferred conditions were to extract the groundwood at 3% consistency with 3% sodium hydroxide at 50°C. (122°F.) for 3 hours. With 10% sodium hydroxide extractions they found 12% of the groundwood had been solubilized while the tear was doubled and the burst factor was tripled.

Kingsbury, et al. (18,19) reported in 1948 and 1949 that groundwoods from several hard and softwood species were consistently made stronger by alkaline bleaching with hypochlorite or peroxides. More recently, Meinke (20) described pretreatment of softwoods with sodium hydroxide and hydrogen peroxide to obtain stronger and brighter refiner groundwoods. Freedman (21) describes how spraying hydrogen peroxide onto several different kinds of pulp in the pulp drier can be used to enhance brightness during shipment and storage.

It will be noted, as this report develops, that the experimental work both substantiates and contradicts some of the results of the earlier workers. The main point of difference is that much shorter processing times are effective.

EXPERIMENTAL

MATERIALS AND METHODS

Groundwood Pulp

An ample supply of a wet-lap, semibleached aspen stone groundwood pulp was obtained from one of the cooperators. This pulp was broken up into smaller fragments as a convenience in handling and placed in plastic bags for storage at 2-4°C. No preservative was used. When this pulp was resuspended in water by treating for 300 counts in a British disintegrator, freeness values of 105 ml. Canadian Standard and 360 ml. Schopper-Riegler were obtained. Other characteristics of this groundwood are given in Table I.

Kraft Pulp

A supply of a commercial dry-lap bleached kraft pulp made from mixed western softwoods (hemlock, Douglas-fir, western red-cedar) was set aside for this program. At different intervals, portions of this pulp were soaked in deionized water and refined in 2.3 kg. batches in a "5-pound" Valley laboratory beater. The freeness level attained, 500 or 700 ml. Schopper-Riegler, will be specified in the section where this pulp is used. After refining, the pulp was drained on a cloth-covered filter box, pressed by vacuum filtration on a Buchner funnel covered with rubber sheeting. The filter cake was broken up mechanically, and stored in plastic bags at 2-4°C. without a preservative. This pulp was held at least 2 weeks before being used to reduce the variation in handsheet properties during the program.

TABLE I

BAUER-McNETT CLASSIFIER DATA FOR THE AGED, DEWATERED PULPS

Pulp	Screen Number[a]		Whole Pulp Fraction, g./100 g.	Whole Pulp Standard Deviation[b]	Classified Pulp Fraction, g./100 g.	Classified Pulp Standard Deviation[b]
Kraft (500 ml. SRF)	> 12		32.7	0.0	43.4	5.0
	> 20		19.5	0.4	18.9	1.8
	> 65		31.4	0.8	30.6	3.1
	>150		7.8	0.6	6.0	0.1
	<150		8.6	1.8	1.2	0.1
		Σ	100.0		100.1	
Groundwood	> 28		3.3	0.5	11.6	2.4
	> 48		11.3	0.4	17.5	1.3
	>100		24.0	0.7	34.4	1.8
	>150		16.0	1.0	23.2	0.5
	<150		45.5	1.9	13.4	1.9
		Σ	100.1		100.1	

[a] > = Retained on screen, < = passing through screen indicated (by difference).

[b] Estimate based on range, 2 determinations for the kraft pulp, 4 replications in the groundwood pulp.

Handsheet Making

The wet pulp crumbs were dispersed in deionized water at 2% consistency for 300 counts in a British disintegrator. After dilution to 0.5% consistency, mixed stock furnishes were prepared by blending the pulp suspension on a volume basis. Where alum is used, it was incorporated at the rate of 2 g. $Al_2(SO_4)_2 \cdot 18\ H_2O$/100 g. dry fiber. Dilute sulfuric acid was used to adjust the pH of the stock to 5.0 where alum was not used. In both situations the water in the handsheet mold (7 liters) was adjusted to the pH of the stock with sulfuric acid before the pulp was introduced.

Aliquots (500 ml., 2.5 g. pulp) of the stock were poured into an 8 by 8-in. Noble and Wood sheet mold and formed into paper on a 100-mesh Monel wire. The white water was not recirculated. After being pressed on blotters, 4 sheets at a time, for 5 minutes at 50 lb./in.^{2} gage pressure, the handsheets were dried on the wire side blotter, blotter side down, on a steam drum (3-5 lb./in.^{2} gage pressure) for 7 minutes.

Testing Procedures

The handsheets were equilibrated first at 20% R.H., 70°F., and then at 50% R.H., 72°F. before testing according to TAPPI procedures. Brightness tests were made within 24 hours of preparation on unequilibrated paper.

COMPARISON OF GROUNDWOOD AND KRAFT FINES

The bonding abilities of the kraft and groundwood fines fractions are compared here by varying, independently, the amount of each kind of fragments in a series of mixed-stock furnishes, making handsheets, and comparing the resulting changes in the measured paper qualities as functions of the fines concentration in the furnish. The fines composition was varied by blending different preparations of the whole pulp and a batch of the same beater load of pulp from which a substantial proportion of the fines had been removed. The fines content of each blended stock preparation was calculated from the experimentally determined fines content of the component pulps.

The "fines-free" or classified pulp were prepared by processing the whole pulp, 30 grams at a time, in a Bauer-McNett classifier for 15 minutes. For cleaner separation, the load on the final classifier screen was reduced by using a series of four screens in the apparatus. For the groundwood, the series was the 28-, 48-, 100-, and 150-mesh screens while the 12-, 20-, 65-, and 150-mesh screens were used with the bleached softwood kraft pulp.

The fractions rejected by the screens were recombined on a cloth-covered filter box and the cycle was repeated until an adequate amount of classified pulp was obtained. The pulp was washed several times with deionized water and then dewatered by vacuum filtration. The filter cake was broken up before the pulp crumb was stored at 2 to 4°C.

Quantitative measurements were made on the whole and classified kraft and groundwood pulps to determine the fines content of these four preparations. The Bauer-McNett classifier was used with the screens specified earlier to process 10-gram aliquots according to an accepted procedure (TAPPI Method T 233 su-64). The dewatered pulps were resuspended for this analysis in exactly the same way they were prepared for making handsheets, that is, for 300 counts in the British disintegrator at 2% consistency in deionized water. The results of the analytical classifications are given in Table I. Freeness values, both Canadian Standard and Schopper-Riegler, were determined on the resuspended pulps and are given in Table II.

TABLE II

FREENESS VALUES OF WHOLE AND CLASSIFIED DEWATERED PULPS
WHEN RESUSPENDED IN DEIONIZED WATER

(40 g. O.D./2000 ml. water, 300 counts in British Disintegrator)

		Freeness	
		Schopper-Riegler, ml.	Canadian Standard, ml.
Kraft	Whole	660	305
	Classified	870	670
Groundwood	Whole	360	105
	Classified	820	510

Three series of blended pulp furnishes were prepared at 0.5% consistency in deionized water using alum at the rate of 2 g./100 g. dry pulp. The relative proportions of the pulps in each blend are given in Table III along with the calculated levels of the fine and coarse fractions. The handsheet data are shown in Table IV.

GROUNDWOOD XANTHIDE HANDSHEETS

The primary focus of this section of this report is concerned with testing whether or not groundwood xanthide would or would not show greater bonding strength than the untreated groundwood. Preliminary trials had shown that blending NaOH solutions and wet lap pulp crumbs (about 30% solids) was unsatisfactory in regard to uniform treatment. As a result, groundwood slurries were prepared by dispersing the pulp in sodium hydroxide solutions. This assured more uniform contact of sodium hydroxide and groundwood particles. In effect, this makes the preparation of groundwood xanthate more like that for starch xanthate (22) than like the one for cellulose xanthate used in rayon fiber production. The method for starch served as a model for the groundwood trials.

TABLE III

COMPOSITION OF FIBER SUSPENSIONS BASED ON TABLE I

	Pulp Ratios									
	Groundwood		Bleached Kraft		Fines in Blend			Coarse Fraction in Blend		
Set Number	Whole, parts	Classified, parts	Whole, parts	Classified, parts	Total, %	Groundwood, %	Kraft, %	Total, %	Groundwood, %	Kraft, %
A I	0	4	0	4	7.3	6.7	0.6	92.7	43.3	49.4
A II	0	4	1	3	8.2	6.7	1.5	91.8	43.3	48.5
A III	0	4	2	2	9.2	6.7	2.5	90.8	43.3	47.5
A IV	0	4	3	1	10.1	6.7	3.4	89.9	43.3	46.6
A V	0	4	4	0	11.0	6.7	4.3	89.0	43.3	45.7
B I	0	4	0	4	7.3	6.7	0.6	92.7	43.3	49.4
B II	1	3	0	4	11.3	10.7	0.6	88.7	39.3	49.4
B III	2	2	0	4	15.3	14.7	0.6	84.7	35.3	49.4
B IV	3	1	0	4	19.3	18.7	0.6	80.7	31.3	49.4
B V	4	0	0	4	23.4	22.8	0.6	76.6	27.2	49.4
C I	0	0	4	0	8.6	0.0	8.6	91.4	0.0	91.4
C II	0	1	3	0	9.8	3.4	6.4	90.2	21.6	68.6
C III	0	2	2	0	11.0	6.7	4.3	89.0	43.3	45.7
C IV	0	3	1	0	12.2	10.0	2.2	87.8	65.0	22.8
C V	0	4	0	0	13.4	13.4	0.0	86.6	86.6	0.0

Reference: Notebook 2816, p. 10.
Coarse Fraction = retained on 150-mesh screen.
Fines = through on 150-mesh screen.

TABLE IV

BONDING ABILITY OF KRAFT AND GROUNDWOOD FINES AND GROUNDWOOD COARSE FRACTION

Set Number	Stock[a] Freeness, ml. S.-R.	Fines in Blended Stock: Groundwood, %	Fines in Blended Stock: Kraft, %	Fines in Blended Stock: Total, %	Basis Weight, g./m.^{2}	Apparent Density, g./ml.	Bendtsen Air Permeation Rate, ml./min.	Burst Factor, m.^{2}	Tear Factor, m.^{2}	Breaking Length, km.	MIT Fold Cycles at 60 g./m.^{2}
A I[b]	830	6.7	0.6	7.3	63.5	0.392	2280	14.9	121	2.82	9
A II	815	6.7	1.5	8.2	65.1	0.407	1460	18.0	121	3.14	15
A III	800	6.7	2.5	9.2	63.2	0.413	1000	19.6	122	3.55	20
A IV	780	6.7	3.4	10.1	61.8	0.418	667	23.0	112	3.86	27
A V	745	6.7	4.3	11.0	63.1	0.423	490	24.0	111	4.18	40
B I[b]	840	6.7	0.6	7.3	64.6	0.394	2110	16.2	136	2.89	10
B II	830	10.7	0.6	11.3	62.7	0.399	1660	16.7	134	2.95	12
B III	800	14.7	0.6	15.3	62.9	0.414	1130	17.7	124	2.96	11
B IV	770	18.7	0.6	19.3	62.6	0.417	830	17.7	123	3.16	17
B V	720	22.8	0.6	23.4	61.4	0.426	659	19.8	125	3.28	17
C I[c]	700	0.0	8.6	8.6	60.3	0.538	56	52.9	128	6.65	907
C II	720	3.4	6.4	9.8	64.0	0.489	132	36.5	127	5.40	286
C III	750	6.7	4.3	11.0	63.9	0.426	411	24.8	110	4.08	38
C IV	780	10.0	2.2	12.2	62.4	0.307	1410+	13.7	72.1	2.81	6
C V	810	13.4	0.0	13.4	63.4	0.314	3170+	6.5	22.1	1.60	1

[a] At pH 4.4 with 2% alum, Schopper-Riegler.

[b] See Table III; 50:50 kraft, groundwood.

[c] See Table III: I-V = 0, 25, 50, 75, and 100% groundwood and 100, 75, 50, 25, and 0% kraft.

Groundwood Xanthate

The hardwood groundwood (203.1 g. as received, 65.0 g. o.d.) was mixed with 900 ml. deionized water and 50 ml. 10N NaOH, for one hour using a variable speed, sparkless electric motor to drive a propeller type of mixer. Carbon disulfide (20 ml., 25.2 g., 0.33 mole) was blended into the pulp dispersion for thirty minutes. The concentrations of reagents at this point were: 5.6 g. dry pulp/100 g. water, 0.48N NaOH, 31 g. NaOH/100 g. dry pulp. A second preparation was blended for three hours, covered, and held overnight at 2 to 4°C. Two additional pulp dispersions were prepared and treated in the same way except carbon disulfide was not used. These preparations served to assess the effect of the sodium hydroxide alone upon the pulp properties.

Groundwood Xanthide Mixed Furnishes

Portions of the treated pulp suspensions were measured out on the basis of the weight of dry, untreated pulp added initially to give a series of furnishes containing 0, 25, 50, and 75% groundwood blended with the bleached softwood kraft pulp. The kraft preparation used here was the same 500-ml. Schopper-Riegler freeness whole pulp used in the preceding experiment.

The furnish blends were diluted to 0.50% consistency in deionized water and adjusted to pH 6.0 ± 0.2 with dilute acetic acid (20% by volume). Iodine solution (about 1N) was added to the stirred suspension until a positive test for excess iodine was obtained with starch-potassium iodide indicator paper. This treatment was also carried out with the alkali control blends as well as the blends containing untreated groundwood and all-kraft pulp; merely to limit variations between the control and test handsheets.

Alum was added after the cross-linking step to aid the deposition of finely dispersed but insoluble xanthide particles. The concentration used was 2 g./100 g. pulp (pH 5.0-5.3). Following a 5-minute period of slow agitation, 500 ml. aliquots were removed (i.e., 2.50 g. pulp) and formed into handsheets (Table V).

Effect of Agitating Pulp in Strong Alkali

The purpose of this experiment is to see if the strength improvements seen in Table V could be due to the mechanical effects of agitating the pulp suspensions for several hours in approximately 0.5N NaOH. A British disintegrator was used to accommodate to volumes desired for the study. This instrument provides intense agitation which has been shown to effect some degree of refining (2).

The groundwood pulp was added to deionized water to give a set of eight 1800-ml. suspensions at 5% consistency. The suspensions were adjusted to pH 6.5, 8.0, or 10.0 and one suspension was prepared in 0.5N sodium hydroxide. For each level of alkalinity, two suspensions were made. One suspension was dispersed for 300 counts in a British disintegrator and the second for 6000 counts, that is, for 2.5 minutes and 50 minutes, respectively. The preparations using the shorter period of agitation were allowed to stand for about 45 minutes afterward to compensate for the differences in the time of exposure.

The treated suspensions were removed from the disintegrator bowl, diluted to 0.5% with deionized water and neutralized. Aliquots of the suspensions were blended with 0.5% dispersions of the whole bleached western softwood kraft pulp used in the preceding sections (i.e., refined to 500 ml. SRF). This led to a series of mixed stocks containing 50, 75, and 100% groundwood. Alum was added at the rate of 2.0 g./100 g. ovendry pulp giving pH 4.5.

TABLE V

GROUNDWOOD XANTHIDE IN HANDSHEETS

	Basis Weight, g./m.^{2}	Apparent Density, g./cm.^{3}	Burst Factor, m.^{2}	Tear Factor, m.^{2}	Breaking Length, km.	MIT Fold Cycles[a]
<u>All-Kraft Furnish</u>						
27-0-1	63.4	0.556	53.0	131	6.59	791
28-0-24	61.1	0.546	53.2	128	6.45	718
<u>25% Groundwood Furnish</u>						
31-10-C Blank control	60.6	0.509	38.5	117	5.54	245
29-10N-1 Alkali control, 1 hr.	60.5	0.560	52.3	104	6.88	631
30-10N-24 Alkali control, 24 hr.	60.0	0.561	51.7	107	7.27	673
27-10-1 Xanthide, 1 hr.	61.4	0.548	45.8	114	6.17	563
28-10-24 Xanthide, 24 hr.	60.7	0.552	46.6	115	6.03	493
<u>50% Groundwood Furnish</u>						
31-20-C Blank control	62.8	0.465	27.1	104	4.20	41
29-20N-1 Alkali control, 1 hr.	57.8	0.556	41.8	85	6.40	322
30-20N-24 Alkali control, 24 hr.	55.2	0.553	41.5	83	6.72	402
27-20-1 Xanthide, 1 hr.	60.3	0.534	32.4	103	5.02	145
28-20-24 Xanthide, 24 hr.	59.3	0.534	35.9	94	5.41	165
<u>75% Groundwood Furnish</u>						
31-30-C Blank control	60.0	0.417	17.3	67	3.35	9
29-30N-1 Alkali control, 1 hr.	55.5	0.556	30.9	58	5.98	135
30-30N-24 Alkali control, 24 hr.	52.5	0.544	31.9	59	5.78	162
27-30-1 Xanthide, 1 hr.	58.3	0.490	24.1	67	4.05	36
28-30-24 Xanthide, 24 hr.	56.0	0.519	26.7	64	4.88	62

[a]Adjusted proportionally to basis weight = 60.0 g./m.^{2}.

The handsheets prepared from these furnishes represent 500-ml. aliquots of the furnish and were formed and dried as described in the preceding sections (see Table VI).

TREATMENTS WITH THE STEAM JET COOKER

Description of the Jet Cooker

The steam jet cooker assembled for the project (see Fig. 1) is based upon the design of North (24) which was modified by Lauterbach (25) to accommodate volumes feasible for laboratory studies. The reason for choosing this cooker design was merely that prior experience had shown that groundwood slurries could be processed in such a unit. There are no major constrictions to inhibit the flow of pulp through the heating zone and thus reduce the uniformity of heating.

A Moyno pump (Type C, Frame 3M), is used to propel the groundwood slurry at a rate of about one gallon per minute. The slurry flows into a one-half inch (O.D.) line just before it enters a 1-1/2-inch pipe used as the cooking chamber. As the pulp enters this chamber, four jets of steam, from 1/8-inch orifices, impinge upon the liquid stream just as it leaves the inlet. The turbulence achieved by the interaction of the converging steam jets and the interactions with the chamber walls cause a rapid exchange of heat from the steam to the groundwood suspension. The heated suspension leaves the 18-inch long cooking chamber through a 3/4-inch line, passes through a back-pressure valve and then into a cyclone separator which frees the liquid effluent from steam released by the reduction to atmospheric pressure.

The time the pulp is exposed to the stated processing temperatures is affected by these characteristics of the process and cooker configuration. The volume of the piping and the pumping rate produce an estimate of 6 seconds

TABLE VI

EFFECT OF MECHANICAL AGITATION IN ALKALI

The Handsheets were Formed at pH 4.5 Using 2% Alum

Furnish Composition	NaOH Concentration	Agitation[a] Time, min.	Mixed Stock Freeness, ml. S.-R.	Burst Factor, $m.^2$	Tear Factor, $m.^2$	Breaking Length, km.	MIT Fold Endurance, cycles	Standard Brightness, %	Basis Weight, $g./m.^2$	Apparent Density, $g./cm.^3$
50% Groundwood	pH 6.5	2-1/2	590	24.3	100	3.52	23	65.4	66.8	0.448
	pH 6.5	50	500	25.1	103	3.47	22	64.5	64.2	0.459
	pH 8.0	2-1/2	540	24.2	109	3.53	24	64.8	64.2	0.449
	pH 8.0	50	500	24.2	106	3.70	26	64.8	64.4	0.454
	pH 10.0	2-1/2	500	24.3	108	3.44	26	65.0	63.6	0.451
	pH 10.0	50	470	23.7	105	3.63	26	64.6	65.6	0.452
	0.5N	2-1/2	400	35.0	90	5.34	125	59.0	58.6	0.519
	0.5N	50	320	38.4	82	5.81	163	51.8	60.1	0.546
75% Groundwood	pH 6.5	2-1/2	470	15.9	71	2.78	6	62.9	66.5	0.413
	pH 6.5	50	435	16.4	70	2.71	5	62.6	65.7	0.418
	pH 8.0	2-1/2	460	16.2	72	2.67	5	62.2	64.3	0.402
	pH 8.0	50	420	16.3	74	2.83	6	62.4	66.3	0.409
	pH 10.0	2-1/2	450	14.8	66	2.56	6	62.6	68.1	0.437
	pH 10.0	50	415	15.7	68	2.90	5	62.1	64.6	0.406
	0.5N	2-1/2	300	30.2	62	5.27	61	51.6	56.3	0.526
	0.5N	50	250	32.2	58	5.43	99	45.9	55.1	0.546
100% Groundwood	pH 6.5	2-1/2	400	10.8	22	2.23	1	61.2	62.2	0.366
	pH 6.5	50	380	11.1	21	2.36	1	61.0	66.0	0.379
	pH 8.0	2-1/2	400	11.3	23	2.22	1	60.9	64.8	0.370
	pH 8.0	50	355	11.7	23	2.27	1	60.9	68.4	0.382
	pH 10.0	2-1/2	380	10.8	23	2.35	1	61.0	68.5	0.376
	pH 10.0	50	360	11.5	22	2.38	1	61.3	64.6	0.378
	0.5N	2-1/2	240	25.7	24	5.43	26	47.2	53.4	0.529
	0.5N	50	230	26.1	25	5.67	28	41.6	52.7	0.439

[a] 2-1/2 Min. = 300 counts, 50 min. = 6000 counts in British Disintegrator.

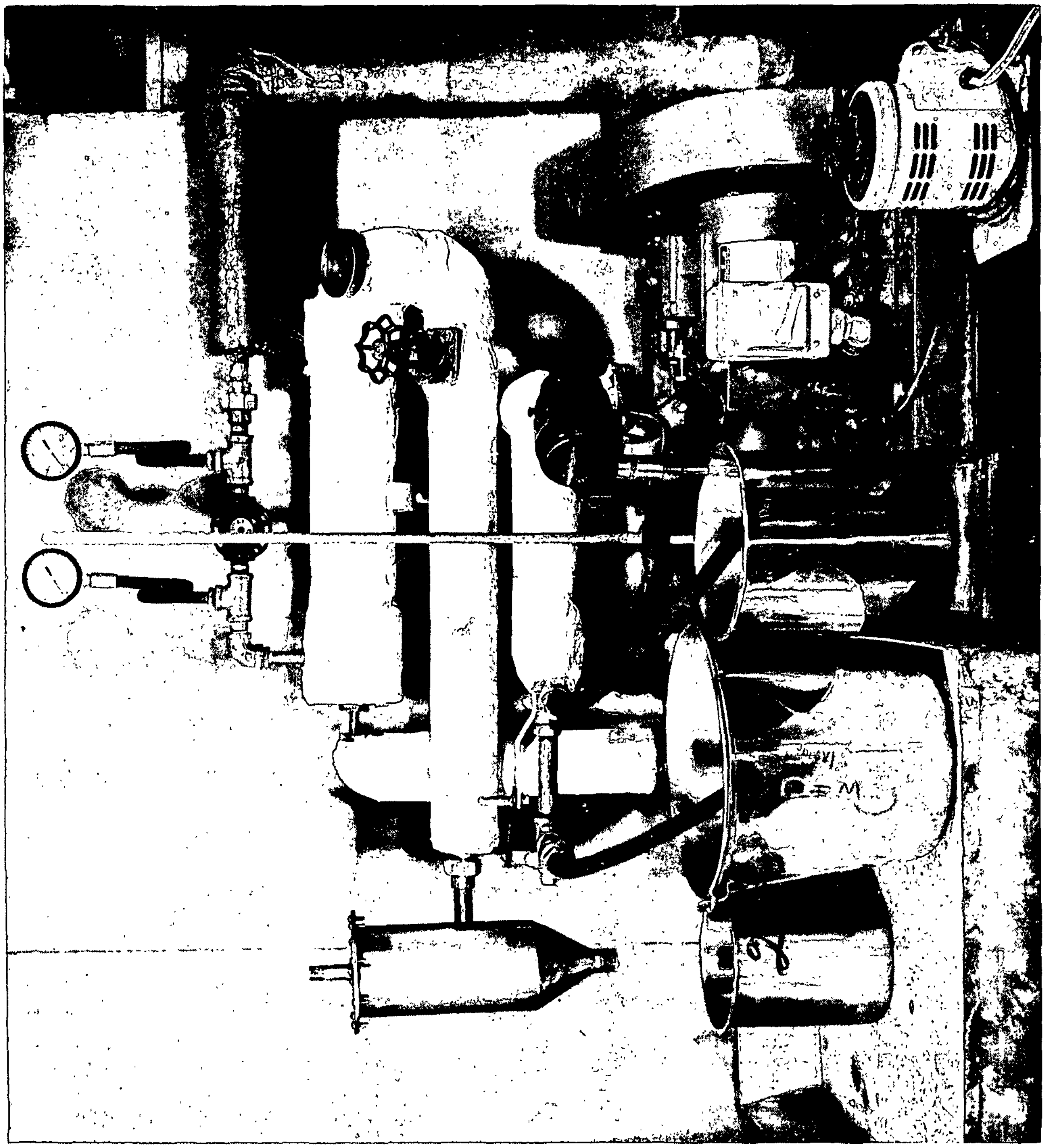

Figure 1. Jet-Cooker Used to Process the Groundwood Pulp. Raw Slurry is Pumped from the Stainless Beaker Which has the Mixer and Rubber Hose and the Processed Pulp is Emitted into the Beaker Marked "2"

at temperature in the cooker itself. Ejection of the effluent into the cyclone separator is accompanied by evaporative cooling. This effect is of only a few degrees Fahrenheit when the process is carried out below about 200°F. At higher temperatures the cooling effect is such that the effluent is collected at about 195 to 200°F. As a result, whatever changes come about during treatments above atmospheric pressure occur during the 6-second dwell in the unit.

The temperature of the process stream is measured ahead of the back-pressure valve and is regulated by manual adjustment of a control valve in the steam line. The back-pressure valve is adjusted to give noncyclic operation and a minimum amount of "blow-by" of uncondensed steam. The setting of this valve is dependent, to some degree, upon the viscosity and heat capacity of the slurry being processed. For improved temperature contol, the operator of the jet cooker has the option of using high pressure (150-160 p.s.i.g.) or low pressure steam (5-40 p.s.i.g.). This option is exercised by opening or closing a by-pass line around an adjustable pressure-reducing valve.

Jet Cooker Operating Procedures

The groundwood pulp was resuspended in 4 liters of city tap water with a laboratory model Lightnin' mixer while 80.0 g. (ovendry basis) of wet groundwood (30.9% moisture) was added. Controls using the same proportions of pulp and water were agitated for 300 counts in a British disintegrator.

The groundwood suspensions were then treated with the combination of reagents called for by the experimental program and then processed in the jet cooker. The jet cooker was started up and adjusted to the desired temperature with water alone. When the operation became stable, the intake line was switched to the groundwood suspension (see Fig. 1). Minor adjustment of the steam was required to compensate for the lower heat capacity and the differing resistance of the slurry through the back pressure valve. Only 2 to 3 liters of the effluent were collected with the initial and final flows being discarded. The treated slurry was cooled rapidly to room temperature (in less than 10 minutes) and then neutralized with dilute acid when required. The consistency of the pulp was determined by vacuum filtration of an aliquot onto a tared sheet of Whatman No. 1 filter paper, oven drying, and weighing. After processing, the pulp consistency varied from 1.65 to 1.98%.

Preparation of Handsheets

The kraft pulp (700 ml. Schopper-Riegler freeness) was resuspended at 2% consistency city tap water and diluted to 0.5% consistency before being blended with the treated groundwood pulps at the same concentration. Pulp ratios of 50/50 and 20/80 kraft to groundwood were prepared for each groundwood treatment. Alum was not used in this series but the pH of the furnishes was adjusted to 5.0 with dilute sulfuric acid.

It is important to note that the procedure outlined above is somewhat different from that used before. Here, the groundwood proportions are based upon the consistency of the treated groundwood slurries, and not upon the quantity of raw groundwood added to the process. (This change was dictated by the variable dilution through the jet cooker.) Therefore, the basis weight values for the different treatments are probably divorced from any significance in regard to the amount of groundwood which may have been solubilized by the treatments.

The data for this series of experiments are given in Tables VII-IX.

TABLE VII

EFFECT OF GROUNDWOOD PROCESSING TEMPERATURE

2% Groundwood Treated in Tap Water

Ref. No.	Groundwood Treatment: Processing Unit	Groundwood Treatment: Processing Temp., °F.	Groundwood Treatment: NaOH, g./100 g. pulp	Groundwood Treatment: pH Before	Groundwood Treatment: pH After	Blend Composition, kraft/groundwood	Freeness[a] at pH 5, ml. S.-R.	Freeness[a] at pH 5, ml. CS	Apparent Density, g./cm.³	Burst Factor, m.²	Tear Factor, m.²	Breaking Length, km.	Tensile Energy Absorption, g.cm./cm.²	Opacity, %	Standard Brightness, %	Bendtsen Air Permeation Rate, ml./min.	Basis Weight, g./m.²
37	British disintegrator	Room (ca. 70°F.)	0	8.2	ND	50/50	580	240	0.435	26.1	119	3.28	35.1	87.1	66.3	ND	62.2
						20/80	470	140	0.391	15.9	74	2.72	20.6	92.3	62.2	ND	62.2
39	Cooker	Room (ca. 70°F.)	0	ND	ND	50/50	620	230	0.428	25.0	119	3.29	39.8	88.1	66.1	ND	63.8
						20/80	480	120	0.393	15.9	70	2.81	22.5	92.4	63.2	ND	63.2
40	Cooker	190	0	ND	ND	50/50	600	230	0.426	27.2	120	3.59	51.8	87.7	66.5	ND	63.5
						20/80	440	140	0.390	16.6	69	2.91	24.0	92.7	62.6	ND	64.0
41	Cooker	230	0	ND	ND	50/50	590	225	0.430	26.5	129	3.53	45.0	88.9	64.9	ND	64.1
						20/80	455	120	0.384	15.7	74	2.78	20.2	93.6	60.9	ND	62.6
42	Cooker	270	0	ND	ND	50/50	600	230	0.435	23.7	124	3.50	43.3	88.2	66.0	ND	62.2
						20/80	425	120	0.392	15.7	70	2.88	23.6	93.0	62.5	ND	62.8
43	Cooker	310	0	ND	ND	50/50	570	240	0.446	25.0	122	3.46	39.8	88.1	65.2	ND	62.5
						20/80	450	110	0.398	15.2	72	2.89	22.1	93.3	61.5	ND	62.9
46	Cooker	190	0	ND	ND	50/50	600	210	0.460	24.8	117	3.49	46.7	88.9	64.9	ND	63.5
						20/80	450	120	0.411	15.0	67	2.88	22.8	94.0	61.1	ND	62.9
47	Cooker	230	0	ND	ND	50/50	630	240	0.456	26.6	126	3.52	45.8	89.1	65.0	ND	62.9
						20/80	440	120	0.410	15.7	69	2.90	23.6	93.8	61.5	ND	62.7
48	Cooker	270	0	ND	ND	50/50	550	210	0.454	24.5	127	3.54	46.3	89.2	64.4	ND	63.8
						20/80	450	130	0.405	15.9	68	2.88	23.2	94.1	61.2	ND	63.6
49	Cooker	310	0	ND	ND	50/50	570	195	0.454	24.1	115	3.58	46.6	89.6	64.5	ND	62.7
						20/80	470	115	0.408	15.8	73	2.87	21.8	94.6	60.3	ND	62.8
62	Cooker	110	0	7.9	7.7	50/50	590	230	0.446	25.6	123	3.69	48.2	88.0	65.5	323	63.3
						20/80	465	125	0.409	16.5	69	2.77	19.0	93.2	61.6	332	63.4
63	Cooker	150	0	8.3	7.7	50/50	620	220	0.453	25.8	121	3.59	43.9	89.2	63.8	314	63.0
						20/80	480	130	0.404	16.5	70	2.98	23.3	94.4	60.7	342	63.8
64	Cooker	190	0	8.1	7.7	50/50	565	220	0.441	25.7	126	3.46	41.9	90.0	63.6	341	63.5
						20/80	470	130	0.396	16.0	70	2.85	23.1	95.0	60.2	361	63.8
65	British disintegrator	Room (ca. 70°F.)	0	ND	8.2	50/50	580	220	0.442	24.0	122	3.16	35.1	90.5	62.4	368	62.3
						20/80	450	125	0.403	15.0	67	2.75	22.2	95.3	59.6	377	62.5

[a]S.-R. = Schopper-Riegler, CS = Canadian Standard.

ND = not determined.
(100% Kraft: S.-R. = 800, CS = 560 ml. and 100% groundwood: S.-R. = 375, CS = 120.)

TABLE VIII

EFFECT OF NaOH CONCENTRATION AND PROCESSING TEMPERATURE

2% Groundwood Treated in Tap Water

Ref. No.	Groundwood Treatment: Processing Unit	Processing Temp., °F.	NaOH, g./100 g. pulp	pH Before	pH After	Blend Composition, kraft/groundwood	Freeness[a] at pH 5, ml. S.-R.	CS	Basis Weight, g./m.²	Apparent Density, g./cm.³	Burst Factor, m.²	Tear Factor, m.²	Breaking Length, km.	Tensile Energy Absorption, g.cm./cm.²	Opacity, %	Standard Brightness, %
55	Cooker	190	0	8.0	7.5	50/50	640	220	63.3	0.449	25.4	125	3.49	43.9	88.0	65.6
						20/80	480	120	63.2	0.408	16.4	68	2.72	18.0	93.4	62.2
56	Cooker	190	0.1	8.7	8.1	50/50	570	225	63.2	0.451	26.3	128	3.51	45.5	88.3	65.7
						20/80	460	130	64.0	0.405	15.8	70	2.99	25.5	93.7	62.0
57	Cooker	190	0.5	10.1	8.7	50/50	590	210	63.1	0.441	24.8	114	3.46	42.6	89.6	64.4
						20/80	460	130	63.3	0.403	16.4	66	2.95	22.6	93.8	61.2
58	Cooker	190	1.0	10.6	9.2	50/50	580	220	62.8	0.445	26.1	123	3.40	35.8	87.6	64.6
						20/80	450	130	62.5	0.406	16.9	72	3.00	22.9	93.3	60.4
59	Cooker	190	5.0	11.6	10.8	50/50	575	200	63.9	0.466	28.9	120	4.05	53.0	87.9	62.4
						20/80	425	120	63.7	0.442	20.3	68	3.57	30.2	93.1	57.9
48	Cooker (from Table VII)	270	0	ND	ND	50/50	550	210	63.6	0.454	24.5	127	3.54	46.3	89.2	64.4
						20/80	450	130	63.6	0.405	15.9	68	2.88	23.2	94.1	61.2
50	Cooker	270	0.1	8.9	8.2	50/50	570	220	62.7	0.464	24.4	124	3.52	38.8	88.7	64.9
						20/80	435	120	63.5	0.410	16.2	74	2.91	24.3	94.0	61.6
51	Cooker	270	0.5	10.0	8.9	50/50	610	210	62.5	0.456	25.1	123	3.48	42.2	88.9	65.1
						20/80	470	120	63.3	0.411	16.0	66	2.93	24.1	94.0	60.9
52	Cooker	270	1	10.5	9.0	50/50	580	250	63.0	0.457	24.9	121	3.61	45.1	88.7	64.0
						20/80	460	130	62.4	0.413	16.3	69	3.05	24.3	93.6	61.0
53	Cooker	270	5	11.5	10.6	50/50	580	195	62.7	0.498	28.5	113	4.24	59.6	86.7	62.7
						20/80	410	100	63.2	0.468	20.5	70	3.68	28.5	92.3	58.4

ND = not determined.
[a]S.-R. = Schopper-Riegler.
CS = Canadian Standard.

TABLE IX

BRIGHTNESS RETENTION WITH PEROXIDE 230°F. COOKER PROCESSING TEMPERATURE

2% Groundwood Treated in Tap Water

Ref. No.	Reagents, g./100 g. pulp NaOH	Reagents, g./100 g. pulp H_2O_2	pH Before	pH After	Blend Composition, kraft/groundwood	Freeness[a] at pH 5, ml. S.-R.	Freeness[a] at pH 5, ml. CS	Basis Weight, g./m.²	Apparent Density, g./cm.³	Burst Factor, m.²	Tear Factor, m.²	Breaking Length, km.	Tensile Energy Absorption, g.cm./cm.²	Opacity, %	Standard Brightness, %	Bendtsen Air Permeation Rate, ml./min.
68	0	0	7.6	7.0	50/50	640	245	62.8	0.442	24.9	123	3.46	42.5	89.2	64.3	339
					20/80	480	125	61.7	0.393	16.0	68	2.82	19.4	94.2	60.2	380
71	0	5	7.3	6.7	50/50	580	240	62.9	0.434	25.6	121	3.40	38.9	87.9	67.9	361
					20/80	470	140	62.5	0.383	15.1	67	2.77	21.8	92.7	64.5	401
69	5	0	11.4	10.1	50/50	525	195	63.5	0.478	30.0	110	4.32	58.6	87.9	61.5	166
					20/80	410	110	64.0	0.444	21.4	67	3.72	29.1	93.4	56.8	146
72	5	5	10.8	9.9	50/50	590	205	62.1	0.460	28.2	113	3.94	45.5	85.8	73.2	221
					20/80	390	100	62.2	0.426	19.8	69	3.58	28.1	90.5	69.8	215
70	10	0	12.0	11.2	50/50	530	160	61.6	0.501	32.9	101	5.04	63.0	85.2	57.9	90
					20/80	320	75	61.8	0.498	26.4	63	4.78	36.7	90.4	52.0	50
73	10	5	11.4	10.7	50/50	500	180	62.2	0.514	32.3	111	4.59	57.5	83.0	69.7	138
					20/80	370	100	62.8	0.487	24.1	64	4.28	35.7	88.7	70.0	92

[a]S.-R. = Schopper-Riegler.
CS = Canadian Standard.

RESULTS AND DISCUSSION

COMPARISON OF GROUNDWOOD AND KRAFT FINES

The classified pulps, as seen in Table I, still contain a measurable amount of fines after being dewatered and redispersed. For the kraft pulps, an average of 1.2% fines was found in the classified pulp and 13.4% fines were found for the classified groundwood. Possibly, the fines in the "fines-free" pulp are due to incomplete separation, but it seems likely that the manipulations required subsequent to classification may generate more fines. In any event, it appears that by the time the classified pulp is prepared and ready to use in handsheets there is a significant concentration of fines in the classified pulp. Removal of fines from the pulps does increase the freeness of the redispersed suspensions as expected. This is shown in Table II.

The range of fines concentrations available for study by the blending technique ranges between that of the whole pulp and that of the classified pulp. The fines content of blends of the whole and classified pulp should be proportional to the amount introduced by each component. This reasoning is the basis for the computations which led to the specification of the fines content of the blends given in Table III.

In Table IV, the kraft fines are increasing while the groundwood half of the furnish is held constant (classified groundwood) in Set A. In Set B, the kraft portion is held constant at 50% classified kraft while the groundwood portion is made up of blends of whole and classified pulp to give a regular increase in groundwood fines. Set C examines the effect of the coarser groundwood or "not-fines" fractions upon the test values as this pulp replaces the whole kraft pulp in the furnish.

In comparing Set A with Set B in Fig. 2 to 4, it is seen that burst, tensile, and the logarithm of folding endurance are linear functions of the fines concentration. The kraft fines improve these test values to a much greater extent than the groundwood fines but the groundwood fines component also has a small positive effect. Thus, it appears that substantial gains in bonding could be made by treatments which make groundwood fines more like kraft fines.

The effect of the two kinds of fines upon tearing resistance is plotted in Fig. 5. Here, the data do not form a linear pattern. Increasing amounts of groundwood fines degrade tearing resistance much less than the kraft fines. This observation along with the burst, tensile, and fold data fits the pattern one observes when comparing better and poorer internal bonding agents.

The apparent density, Fig. 6, increases more rapidly with the kraft fines. This is reflected by the lower porosity in Fig. 7 and lower freeness in Fig. 8. This pattern of effects is consistent with the idea that kraft fines may be more flexible and compactable than the groundwood fines.

The data for the "C" series of handsheets display increasing freeness as increasing amounts of classified groundwood replace the whole kraft pulp. This is accompanied by decreasing density, burst, tensile, and fold, and by increasing porosity. In Fig. 9, it is seen that tensile and burst are linearly inversely proportional to the groundwood content of the blend. In contrast, tearing resistance does not start to drop until about half of the whole kraft pulp has been replaced by classified groundwood. In view of the trend seen in Fig. 5, the bow in the curve in Fig. 10 may reflect improved tear due to a lower concentration of kraft fines.

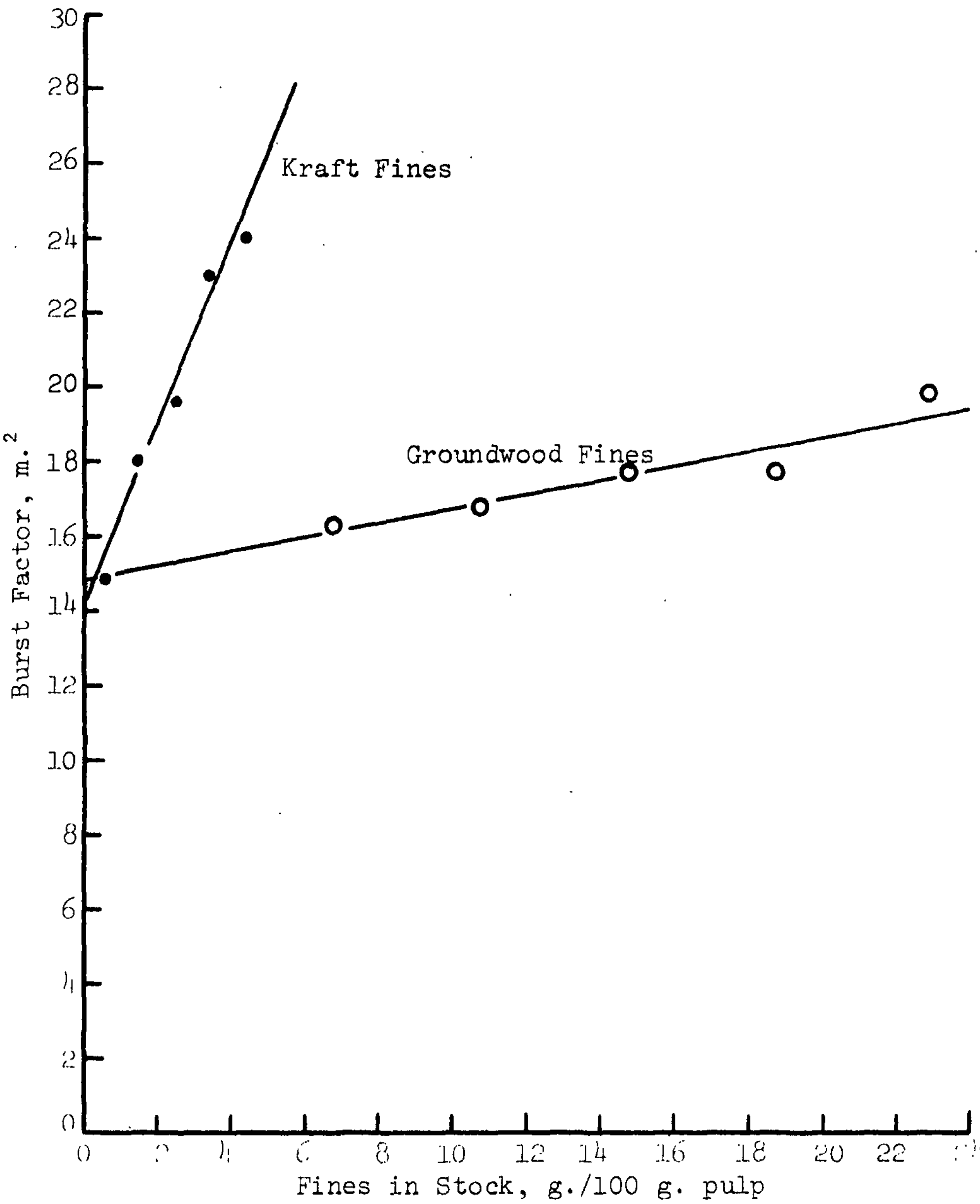

Figure 2. Bursting Strength vs. Fines Composition in 50/50 Blends of Kraft and Groundwood with 2% Alum

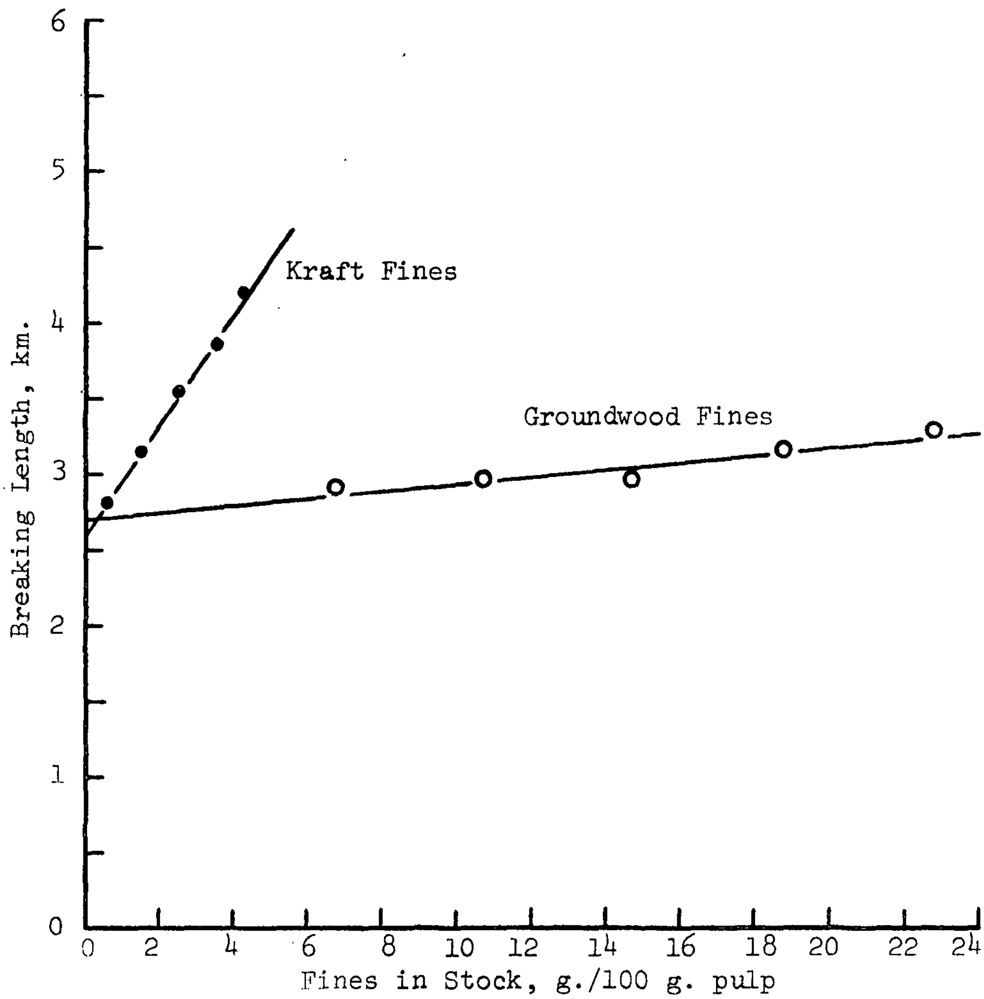

Figure 3. Tensile Strength vs. Fines Composition in 50/50 Blends of Kraft and Groundwood with 2% Alum

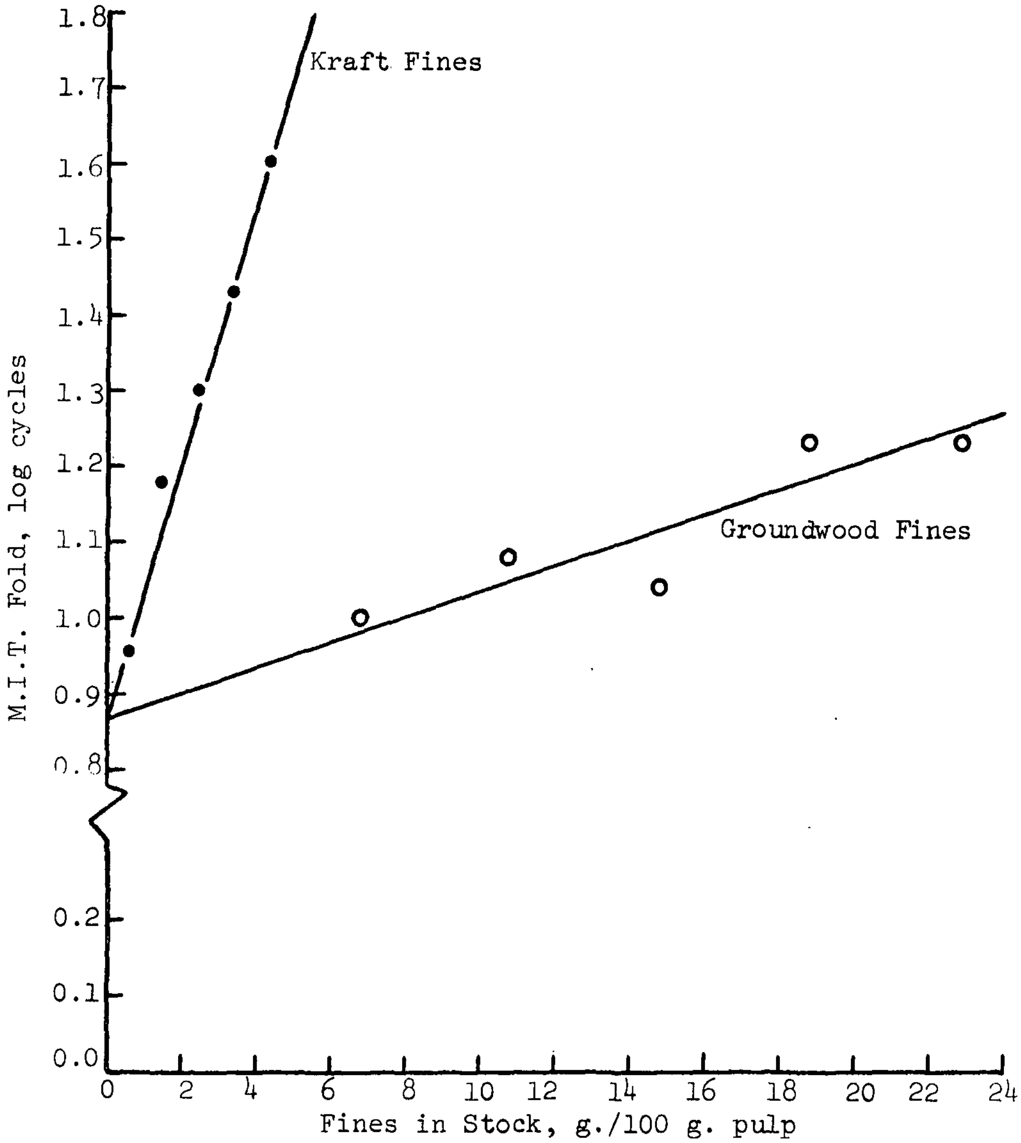

Figure 4. Folding Endurance vs. Fines Composition in 50/50 Blends of Kraft and Groundwood with 2% Alum

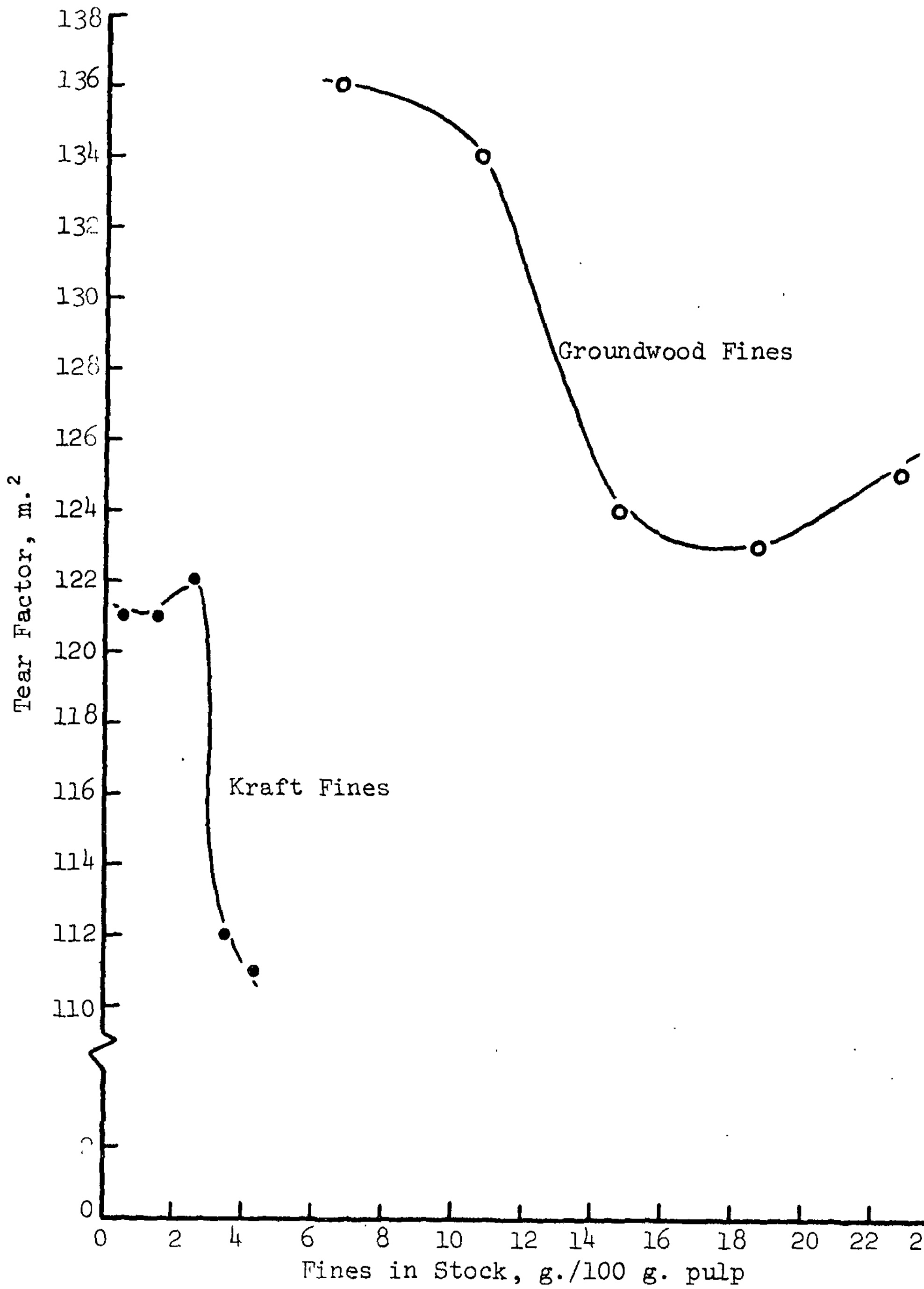

Figure 5. Tearing Resistance vs. Fines in 50/50 Kraft/Groundwood Mixed Stock

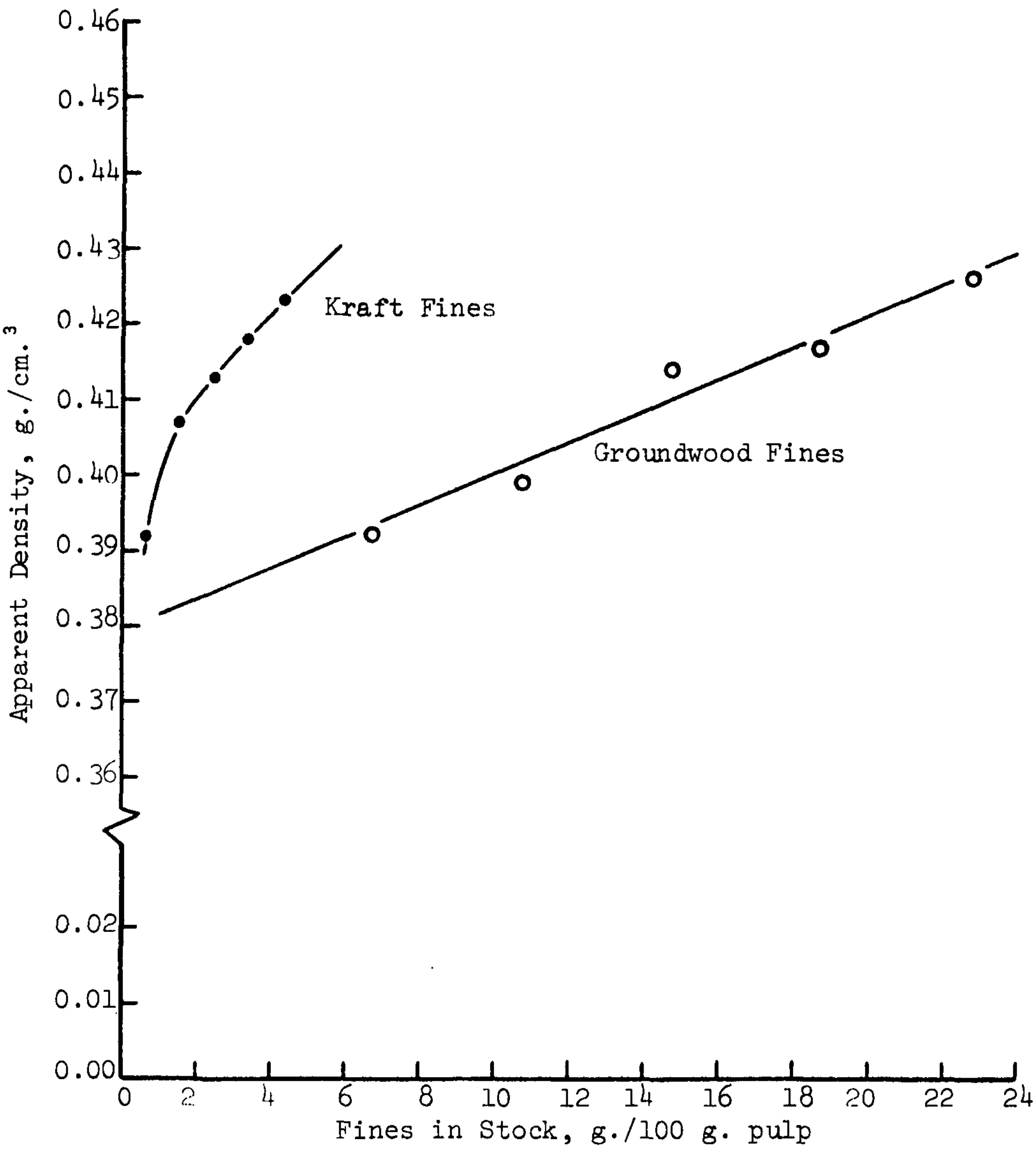

Figure 6. Apparent Density vs. Fines Concentration in 50/50 Kraft/Groundwood Mixed Stock

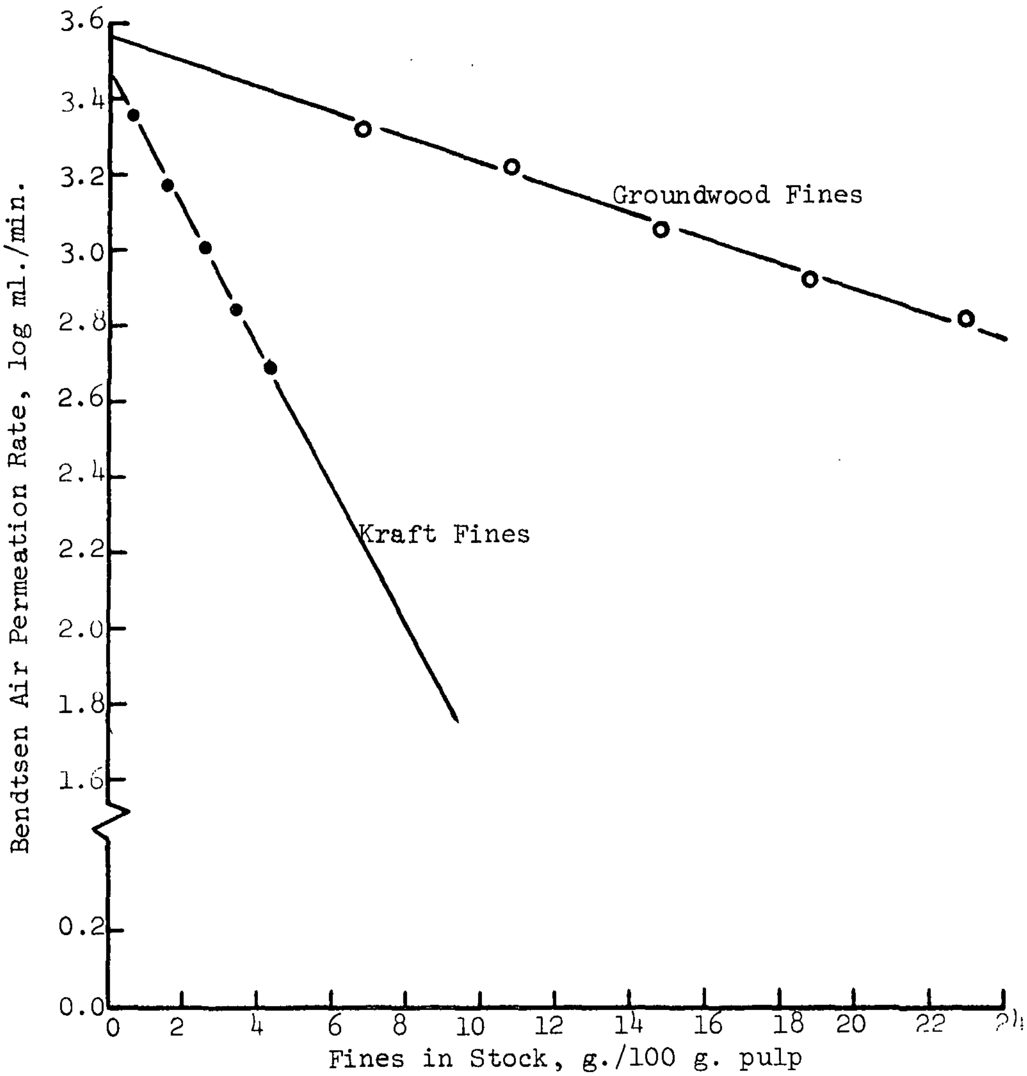

Figure 7. Bendtsen Air Permeation Rate vs. Fines Concentration in 50/50 Kraft/Groundwood Mixed Stock

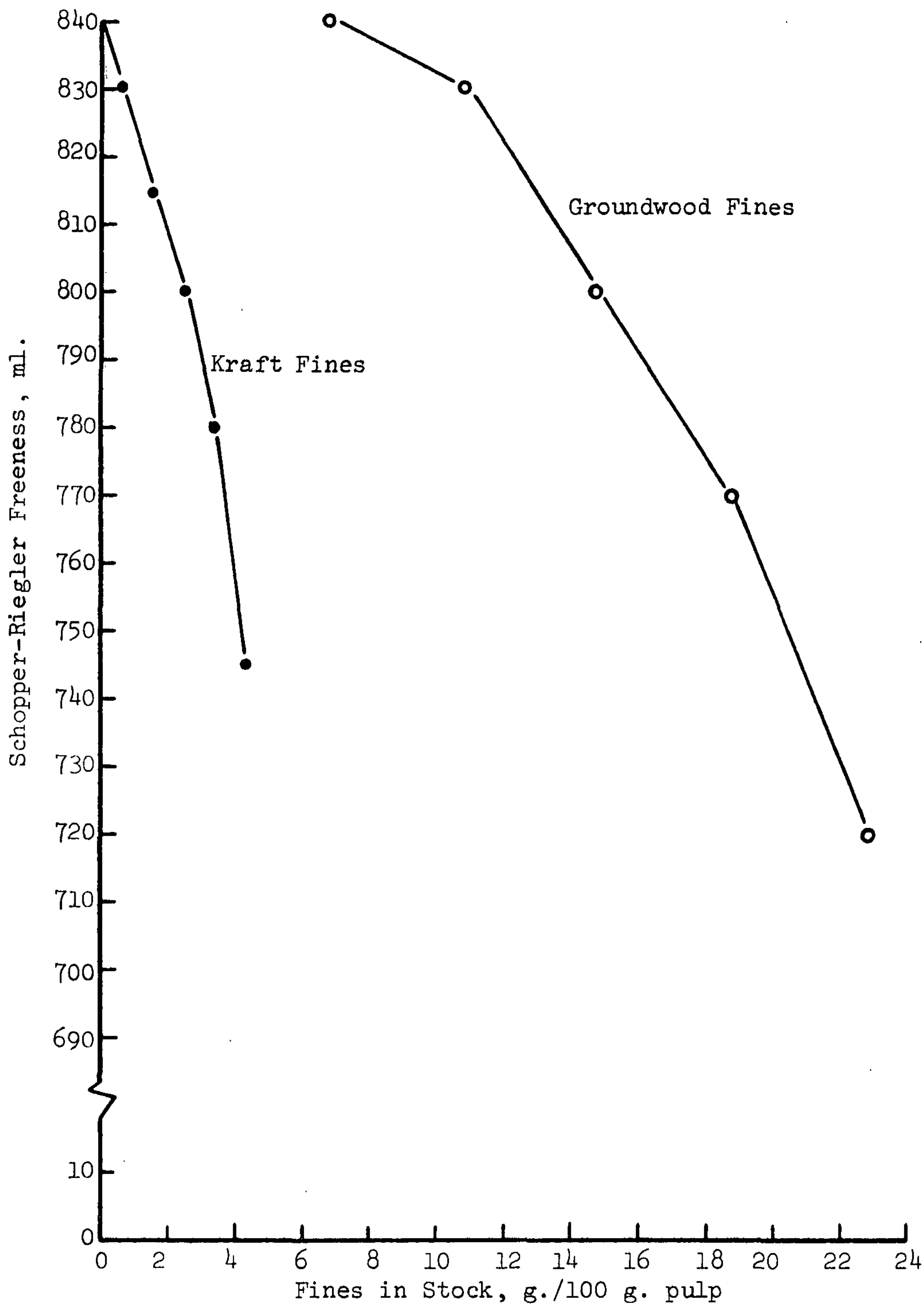

Figure 8. Mixed Stock Freeness *vs*. Fines in 50/50 Kraft/Groundwood Blends

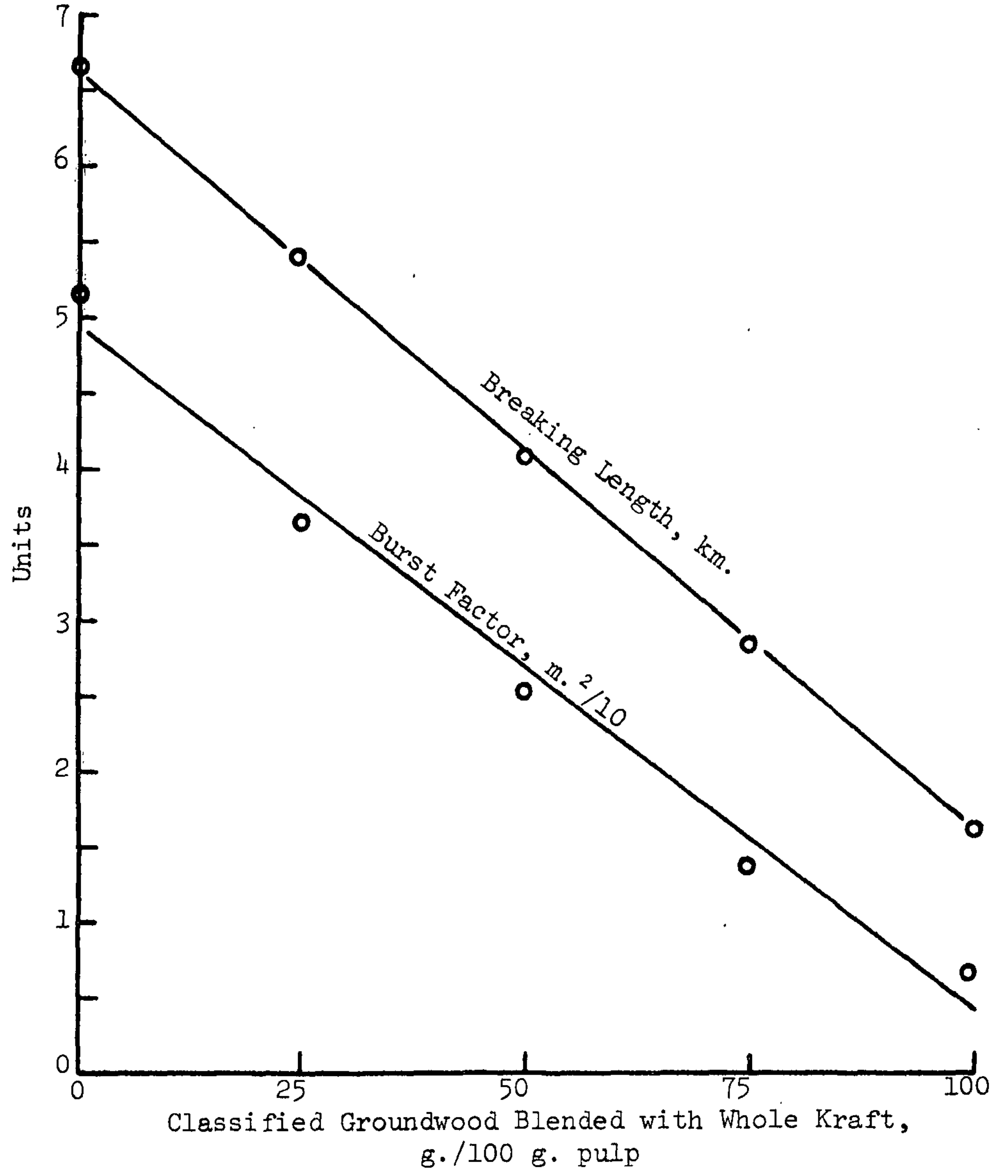

Figure 9. Tensile Strength vs. Classified Groundwood Blended with Whole Kraft Pulps

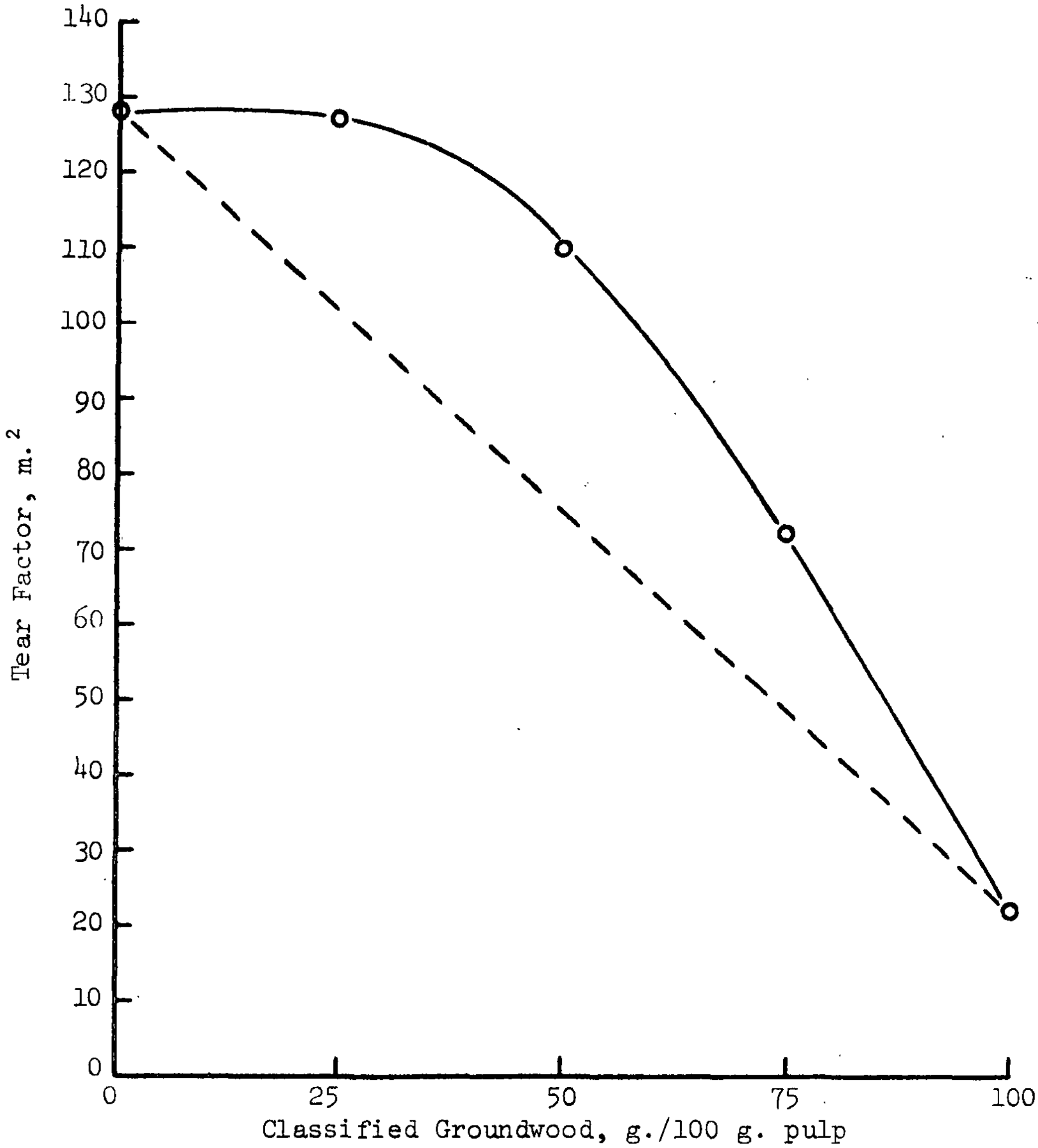

Figure 10. Tearing Resistance vs. Classified Groundwood Blended with Whole Kraft Pulp

Several properties of paper have been shown to be directly related to the fines content in 50/50 blends of kraft and groundwood pulps. In every case, kraft fines were more effective in changing the test values than the groundwood fines. Kraft fines per unit weight are better bonding agents as shown by the tensile, burst, fold, and tear data, and are better pore-plugging materials as shown by the freeness tests and by the Bendtsen air permeation rate values. These results demonstrate that groundwood fines are inherently poorer bonding agents than kraft fines and that hardwood groundwood is not a good source of fines for improving the bonding of bleached kraft fibers in place of the fines derived by beating the kraft pulp itself.

Inasmuch as the basis weight of the handsheets, which were made from 500-ml. aliquots of the pulp suspensions, are not greatly different it is not likely that the difference in the performance of the kraft and groundwood fines is due to large differences in fines retention.

It is concluded that both the coarse and fine fractions of this groundwood would benefit from treatments leading to increased bonding ability. Consequently it is reasonable to proceed with chemical procedures for improved bonding even though the major effect is likely to be upon the fine fraction.

GROUNDWOOD XANTHIDE HANDSHEETS

The results of the testing program are shown in Table V. Inspection of these data reveals that the chemical treatments given the groundwood do indeed result in significantly stronger handsheets. However, the groundwood treated only with sodium hydroxide produces handsheets stronger than those made from the groundwood xanthide. In fact, with 25% groundwood in the furnish, the alkali control handsheets have higher breaking length values than the all-kraft handsheets, while burst, tear, and fold are comparable or slightly lower.

Similar trends are seen with the 50 and 75% groundwood furnishes. The alkali-control sets have higher values for density, burst, breaking length, and folding endurance than the groundwood xanthide sets which in turn are stronger than the sets made with the untreated groundwood. The tear factor is lower for the alkali-control handsheets as would be expected if improved bonding were responsible for the higher burst, tensile, and fold values. On the other hand, the groundwood xanthide handsheets have tear factors very nearly the same as the untreated groundwood control papers while having enhanced burst, fold, and tensile strength values.

The basis weights of these sets of handsheets, by design, reflect the solubilizing effects of the different treatments given the groundwood pulp. This came about by basing the proportion of the groundwood in the mixed stock upon the dry weight of the groundwood before treatment. It is evident in Table V, that the basis weight of the handsheets decreases with the length of the treatment and that the alkali treatment alone produces the lowest handsheet weights. Since reacting the alkali-groundwood with carbon disulfide would produce the xanthate derivative and increase the pulp solubility, it is evident that converting the groundwood xanthate to the insoluble xanthide derivative does reverse the solubilizing effects of the two reagents. Very likely, part or most of the polysaccharide portion of the soluble pulp fraction is redeposited on both groundwood and kraft portions of the mixed stock in the manner found with starch xanthide (23).

Inasmuch as the strength data given in Table V have been treated to minimize this effect of basis weight variations, it is important to point out that the raw data (not shown) also displayed the same trends and relative effects according to treatment as the adjusted data. The relationships already discussed are not the result of following the convention of comparing the effects of the treatments at a common basis weight.

It is concluded that the more attractive line of research lies in treating the groundwood with sodium hydroxide. The strength enhancement is greater, the treatment is less complex, and would require less stringent environmental protection procedures as compared with the production of groundwood xanthide. The loss of brightness (obvious but not measured) and the loss of pulp due to the effect of the sodium hydroxide are the primary negative aspects of this treatment which must be minimized.

<u>Effect of Agitating Pulp in Strong Alkali</u>

In the preceding section, the strength values for the handsheets made from groundwood soaked in approximately 0.5<u>N</u> sodium hydroxide showed improved strength properties over those made from groundwood xanthide or from the untreated groundwood. This observation led to the conclusion that the sodium hydroxide was responsible for this enhancement. On the other hand, it seemed possible that the mechanical agitation used to disperse the groundwood in the sodium hydroxide could also be involved. Groundwood suspensions in the range of 5 to 6% consistency are rather heavy and do require fairly intense agitation. This is especially true in the instances where the pulp must also be rendered free of nits for proper use in paper. Although the alkaline medium assisted the preparation of a well-dispersed pulp at high consistency, there was a period of one to four hours in which the pulp was stirred rather vigorously. The purpose of this agitation was to assure that the pulp and sodium hydroxide were thoroughly mixed and to facilitate the reaction of the alkali groundwood and carbon disulfide to form groundwood xanthate. The alkali control preparations were agitated for the same periods of time as the xanthate preparations so that only the effect of xanthation was investigated in the comparisons between the alkali control and the xanthated pulp for the one-hour and twenty-four hour intervals. It was felt that, without a control sample, there was not enough information to determine whether the strength improvements were due to the alkali alone or were due to the longer periods of mechanical agitation.

The data in Table VI have been grouped according to the groundwood composition of the fiber blends. Inspection of the column for the mixed stock freeness reveals that there is an effect attributable to the duration of agitation. The 6000-count (50-minute) treatment did reduce the freeness more for all the blends for all the different alkali concentrations. The fact that these differences are very small for the 100% groundwood series points to the uncertain basis of the freeness measurement. Apparently, the mixed stock freeness values are more sensitive to differences in groundwood particle size, fines composition, or other parameters which are changed by refining, than the measurement made on the all-groundwood furnishes.

In general, there is a fairly consistent trend, which is small in many cases, which indicates that extending the treatment in the British disintegrator from 300 to 6000 counts does slightly improve the bonding of the pulp. However, the effect of the alkali concentration is much more evident. Almost no effect is seen at pH 6.5, 8.0, and 10.0, although there is a great improvement in burst, tensile, and fold values when the groundwood is treated with the half-normal sodium hydroxide. This improvement is of such magnitude that the 100% groundwood handsheets for the 0.5N NaOH treatment equal the burst, tensile, and fold values of the 50% groundwood handsheets from the pH 6.5, 8.0, and 10.0 treatments. The tearing resistance of the all-groundwood papers is lower than that of the 50/50 kraft/groundwood blends for the three lowest alkali levels. It is noted that the tear resistance of the all-groundwood sheets is improved, along with burst, tensile, and fold, by the strong alkali treatment. The enhanced bonding obtained by treating groundwood in 0.5N sodium hydroxide is also evident in the data for the mixed stock furnishes.

The undesirable features of the strong alkali treatment are seen in the values for the standard brightness and basis weight tests. Some 13-19 brightness points are lost by this treatment in the case of the 100% groundwood papers. The basis weight values suggest that about 20% of the groundwood is lost by the strong alkali treatment. That is, the basis weight of these handsheets is only about 80% of that of the handsheets from the milder treatments. It is not known whether the fiber loss is due to extraction alone or whether part is due to more and smaller fines being lost during formation of the sheet.

The apparent density of the handsheets is increased by the strong alkali treatment. Whether this is desirable or undesirable is a matter of one's viewpoint. Groundwood is frequently used to increase the bulk of paper. Hence, it might be argued that the strong alkali treatment reduces the range of qualities which may be built into the paper structure.

The foregoing discussion brings out that the main reason for the improved bonding is the high concentration of sodium hydroxide and not the mechanical energy imparted for mixing. In addition, these data reinforce those of the preceding experiment which showed substantial gains in bonding strength could be obtained by treating groundwood in approximately 0.5N sodium hydroxide. The data in Table VI indicate that the minimum sodium hydroxide concentration for significant bonding enhancement is in excess of pH 10 (about 0.0001 normal in regard to free NaOH).

Procedures to limit the brightness lost with the strong alkali will need to be developed along with selection of the optimum sodium hydroxide concentration maximum strength and maximum yield.

TREATMENTS WITH THE STEAM JET COOKER

Heat Treatments in Tap Water

Groundwood slurries were pumped through the jet cooker at 2% consistency using settings of 110, 150, 190, 230, 270, and 310°F. Control runs consisted of one slurry pumped through the cooker without using steam and two dispersions prepared at room temperature in a British disintegrator. One room temperature control was run at the beginning and the second at the end of this series of treatments. The processing was done at pH 8 since that was the value obtained by suspending the pulp in the slightly alkaline city tap water. It will be noted in Table VII that the pH of the treated suspensions was reduced in the cooking process. This trend will be repeated and be more obvious in the data for the alkaline treatments to be discussed later.

The pulps were tested by preparing handsheets from mixed furnishes containing 50 and 80% treated groundwood blended with bleached softwood kraft. These data are found in Table VII.

The greatest effect of heat processing is observed in the data for breaking length and for tensile energy absorption. As illustrated in Fig. 11, the breaking length is raised by treating the pulp in the jet cooker with the

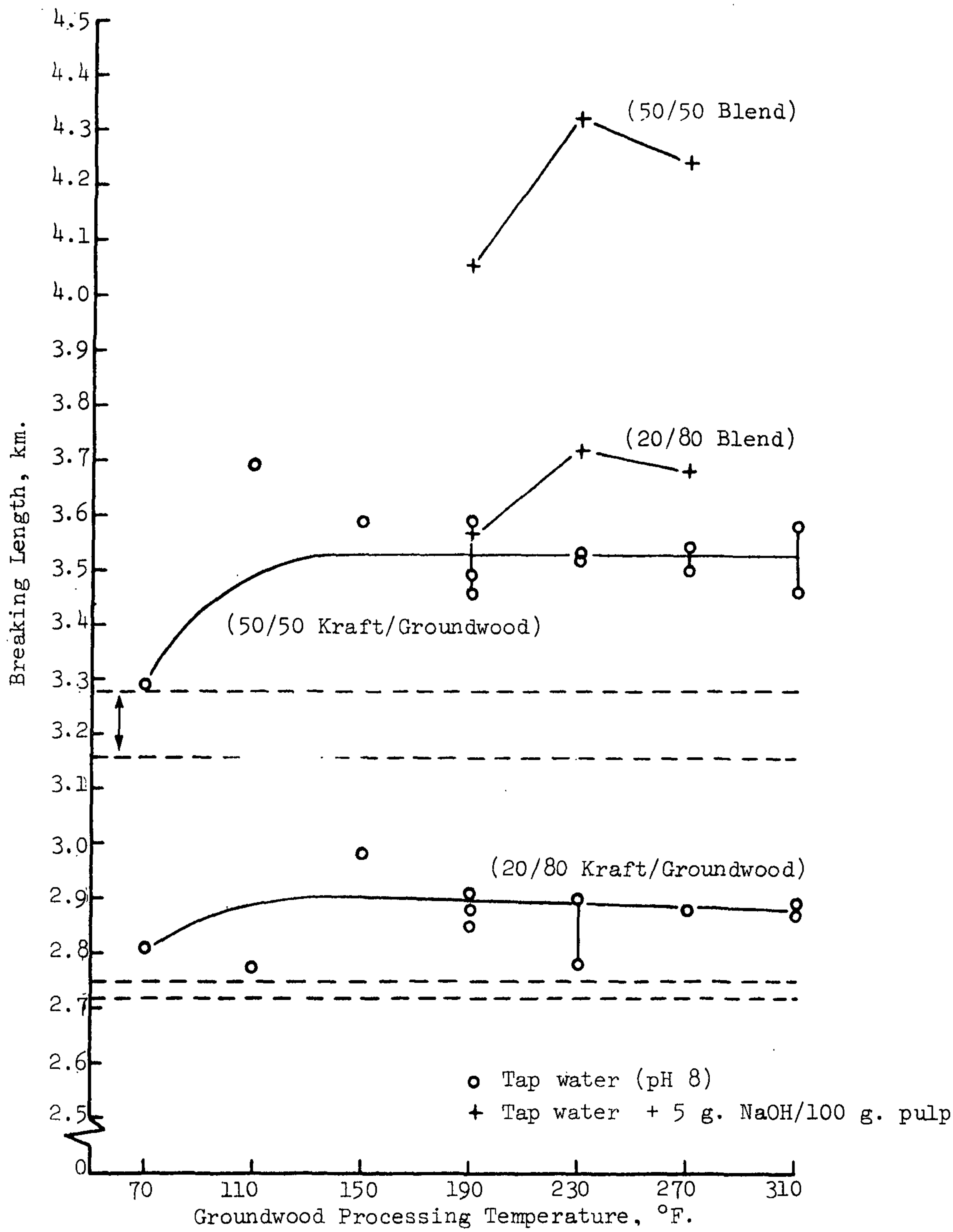

Figure 11. Processing Temperature vs. Breaking Length. Broken Lines Indicate Groundwood Dispersed at Room Temperature in British Disintegrator

steam turned on. Merely pumping the pulp through without using steam produces data no different than the British disintegrator dispersions. Over a temperature range of 150 to 310°F. it appears fairly certain that varying the processing temperature has no beneficial effect. However, within that range, the breaking length is elevated from about 3.2 km. to 3.5 km. for the 50/50 and from about 2.7 km. to 2.9 km. for the 20/80 kraft/groundwood blends, compared with the disintegrator dispersions. This represents improvements of the order of 8 to 10%.

The tensile energy absorption data are seen in Fig. 12 to follow a similar pattern except the major improvement appears with the data for the 50/50 blend, about 30%, while it is marginal for the 20/80 blend. (Both Fig. 11 and 12 contain data from alkali treatments which will be discussed later on.)

Jones (13) found no breaking length improvement with stone groundwood vigorously agitated in water for 15 minutes at 180°F. However, he does not specify whether hardwood or softwood groundwood was used. Lindberg and MacLaurin (12) obtained breaking length enhancements of the order of 10% when they heat-treated southern pine stone groundwood. On the other hand, in contrast with the findings of these workers, burst is not improved when the hardwood stone groundwood was heated in the jet cooker. These data, shown in Fig. 13, are observed to fall within, or very near to, the range of values obtained with the controls not passed through the jet cooker.

The freeness of the mixed furnishes is not changed significantly by jet-processing the groundwood nor are the brightness and opacity values for the handsheets from these furnishes. Tearing resistance is apparently unaffected by the steam treatment although there may be some improvement evident in the sets of handsheets from the 230 and 270°F. exposures in the 50/50 blends. The

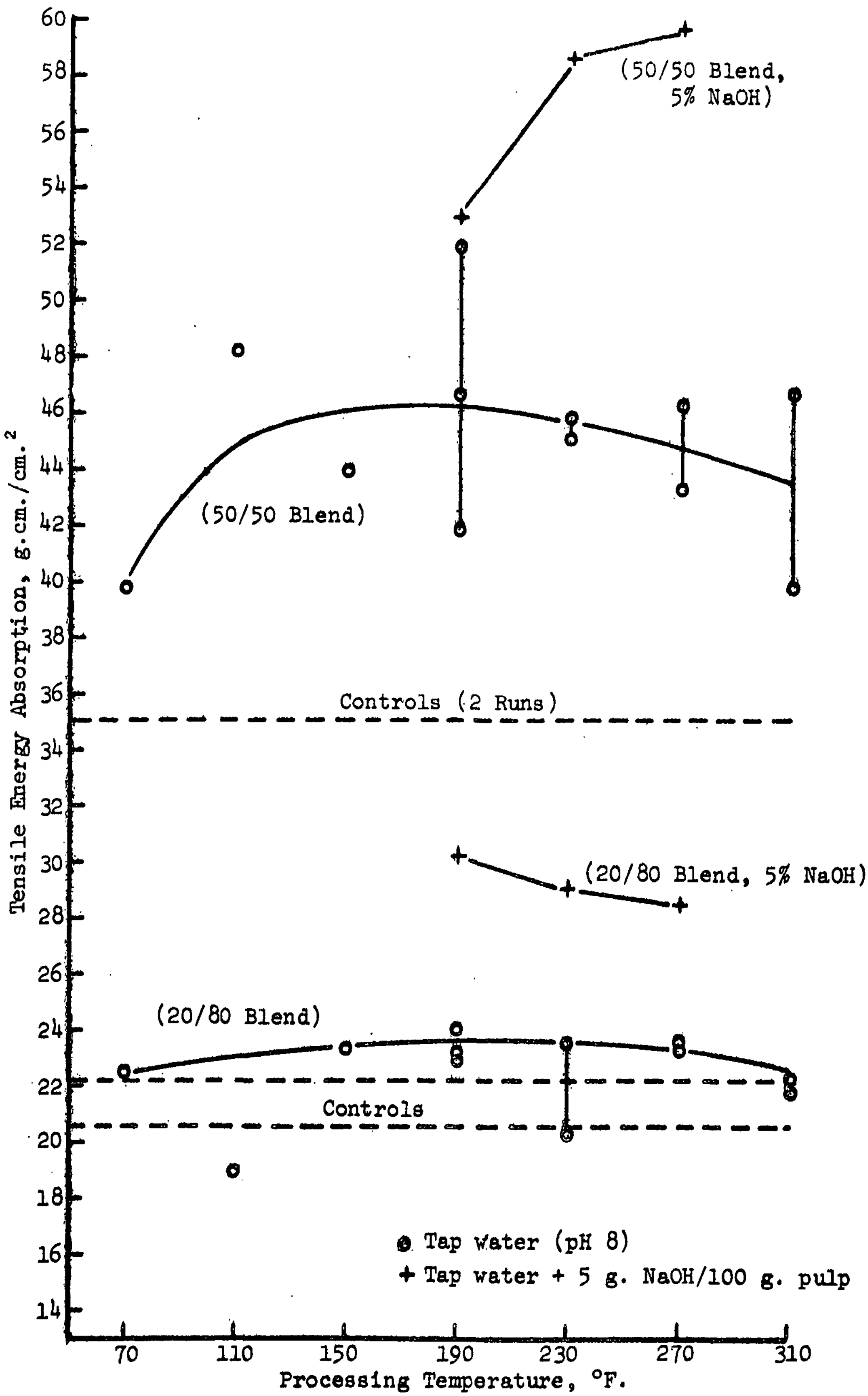

Figure 12. Tensile Energy Absorption vs. Processing Temperature. Broken Lines are for Groundwood Dispersed

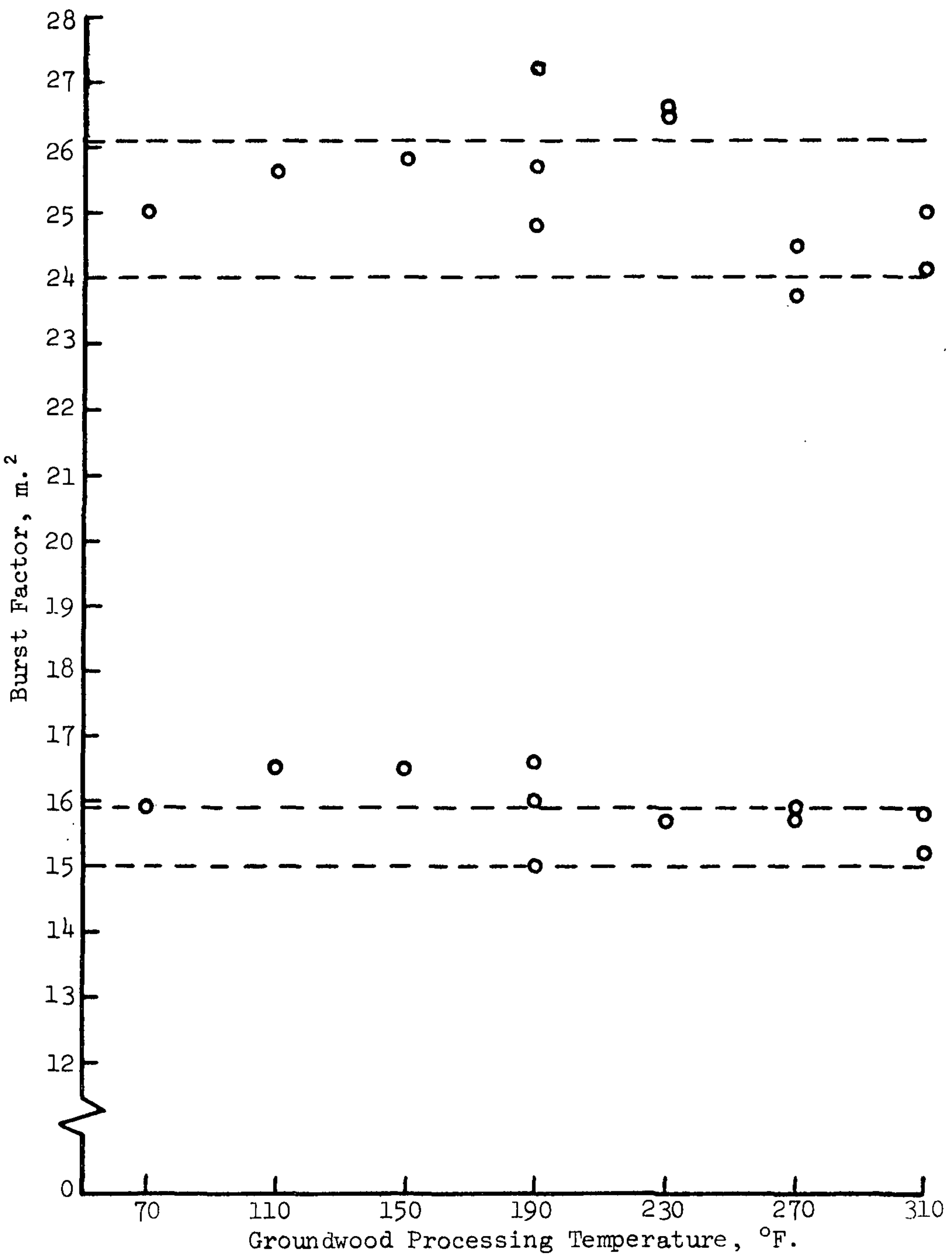

Figure 13. Burst Factor vs. Processing Temperature. The Broken Lines Indicate Values Obtained with Unheated Groundwood Dispersed in a British Disintegrator

apparent density values of the handsheets present a scattered pattern which appears to center on the range of the control sets.

The net effect of treating this hardwood stone groundwood in the jet cooker is to improve the breaking length and tensile energy absorption of mixed stock handsheets made from 50/50 and 20/80 kraft/groundwood blends. Varying the processing temperature between 150° (possibly 110°) and 310°F. appears to have no effect upon the results. Some heat is necessary since merely pumping the pulp through the cooker does not change its properties. The question still remains whether or not a fresh sample of this pulp, straight from the mill, would respond to the heat treatments. It is likely, however, that aged pulp stored as wet lap would respond since that is the form in which the pulp was used in these experiments.

Sodium Hydroxide Treatments

Groundwood slurries adjusted to contain 0.0, 0.1, 0.5, 1.0, and 5.0 g. NaOH/100 g. dry pulp were cooked at 190 and 270°F. Handsheets were prepared from furnishes containing 50 and 80% groundwood blended with kraft pulp for evaluating changes produced by this combination of conditions. Data for these handsheets are found in Table VIII.

The pH values of the groundwood suspensions are seen in Table VIII to be lowered by heating in the jet cooker. This indicates part of the NaOH is consumed by wood acids either present in the pulp or produced during the process. The range in values increases as the NaOH concentration increases up to 1% indicating the alkali consumption increases with the alkali available. Owing to the logarithmic nature of the pH scale, this generalization may also hold for the range between 1 and 5% NaOH. Improved extraction conditions or greater potential for chemical degradation would both fit this trend with increasing levels of caustic.

The physical properties of the handsheets change very little as the NaOH concentration is raised from 0 to 1%. An upward trend, such as in Fig. 14, is suggested in the data for the 270°F. processing, which indicates the minimum or threshold alkali requirement may be near the 1% sodium hydroxide level. This is equivalent to an initial NaOH concentration of 0.005N. The breaking length levels increase significantly as the caustic concentration is raised to 5% and there is greater improvement with the 270° temperature than the 190°F. treatment. At the 5% NaOH level the increment between temperatures is about 0.2 km. for both the 50/50 and 20/80 kraft groundwood blends. In regard to the pulp jet cooked without NaOH, the 5% treatment is 21% higher for the 50/50 blend and 27% higher for the 20/80 blend although the increment is about the same in both cases (0.75 vs. 0.8 km.). The untreated controls listed in Table VII for pulps merely dispersed in a British disintegrator provide a measure of the combined effects of heat and alkali. For the 50/50 blend, the breaking length has been improved 31% at 270°F. with the 5% NaOH and 24% at 190°F. With the 20/80 blend, the improved levels are 37 and 30%, respectively. On the basis of the trends illustrated in Fig. 14, it appears that groundwood treated with 2.0 to 2.5% NaOH in a 20/80 kraft groundwood blend would equal the breaking length of a 50/50 blend using the untreated and unheated groundwood.

The tensile energy absorption of the trial handsheets follows similar trends as those discussed for the breaking length. The 5% NaOH-270°F. combination yields values 70 and 28% higher than the untreated, unheated controls for the 50/50 and 20/80 blends, respectively. At 190°F. with 5% NaOH, tensile energy absorption values are 35 and 81% higher on the same basis of comparison.

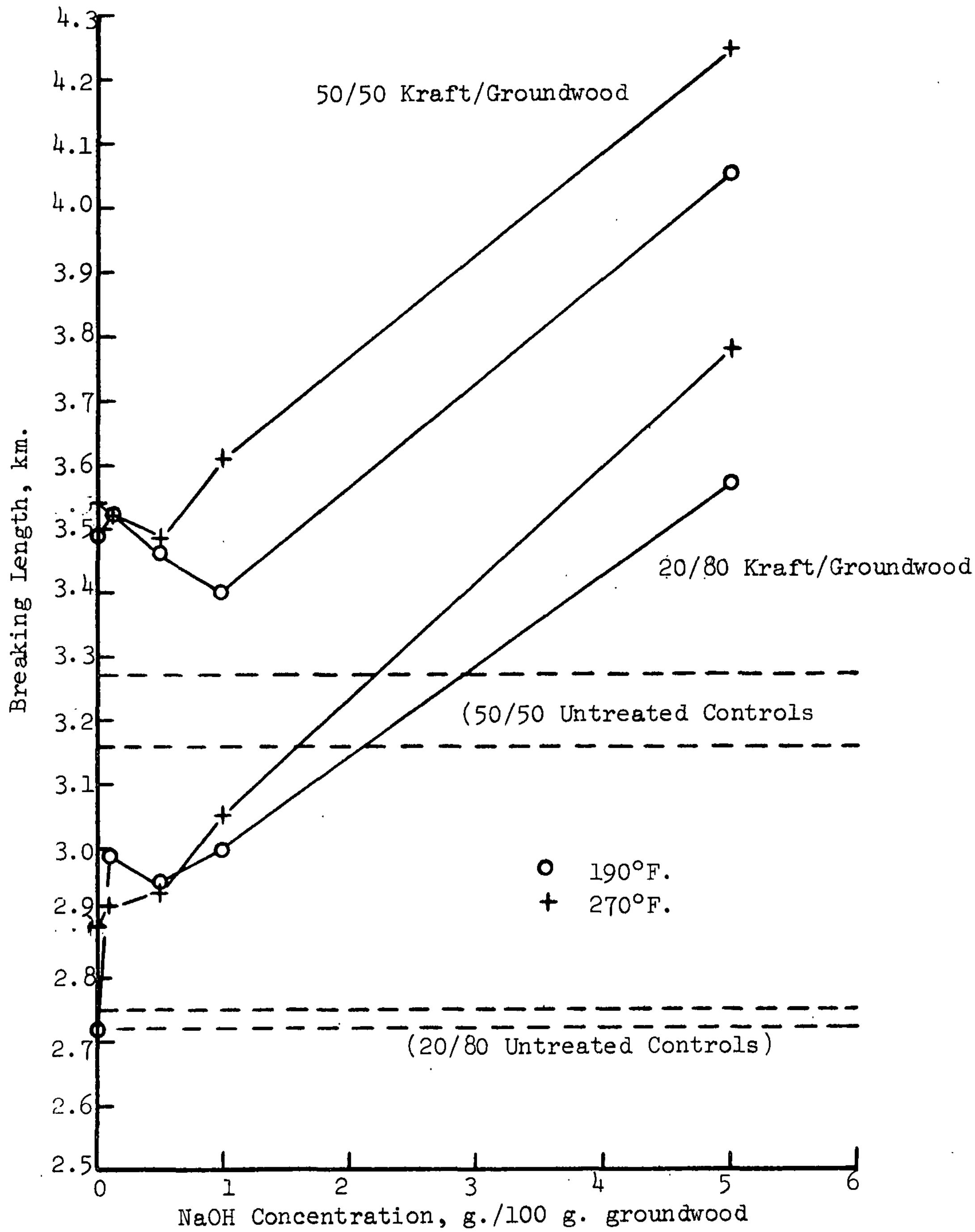

Figure 14. Breaking Length vs. Alkali Concentration. The Broken Lines Indicate Values Obtained with Untreated and Unheated Groundwood

It is obvious on the basis of the trends shown in Fig. 15 that more than 5% NaOH is needed for a 20/80 blend to equal the tensile energy absorption of a 50/50 blend using untreated groundwood.

The burst factor, Fig. 16, is greatly improved with the 5% NaOH groundwood in both furnishes. Unlike the data shown in Fig. 14 and 15, the processing temperature had little effect upon the results. As before, NaOH concentrations of 1% and lower were ineffective. In Fig. 17, it is seen that the apparent density of the handsheets increases as the alkali concentration is raised above 1% NaOH and that the higher processing temperature produces higher density handsheets.

The optical properties of the alkali groundwood handsheets are surprisingly little affected by the range of 0-5% NaOH. There is a downward trend in Fig. 18 with increasing amounts of caustic for both mixed stock blends. However, only the 5% addition rate yields values outside the ranges found with groundwood dispersed in the British disintegrator. The processing temperature seems to have little effect upon the changes that are noticeable. Brightness losses of about 2 to 4 points are recorded as the NaOH concentration increases from 0 to 5% with the jet cooked pulps. Foote and Parsons (16) note losses of 1.2 to 3.7 points brightness per 1% NaOH with unblended pulps.

Brightness Retention

Foote and Parsons (16) discuss procedures for bleaching alkali-treated aspen stone groundwoods to restore the lost brightness. They caution that the pulp must be thoroughly washed before bleaching to avoid excessive consumption of reagents. Both hypochlorite and peroxide bleaching were used with additional strength gains noted and shown to be due to the alkali in the bleach liquor. Apparently, Foote and Parsons did not attempt to add bleach during the initial strength-promoting caustic treatment.

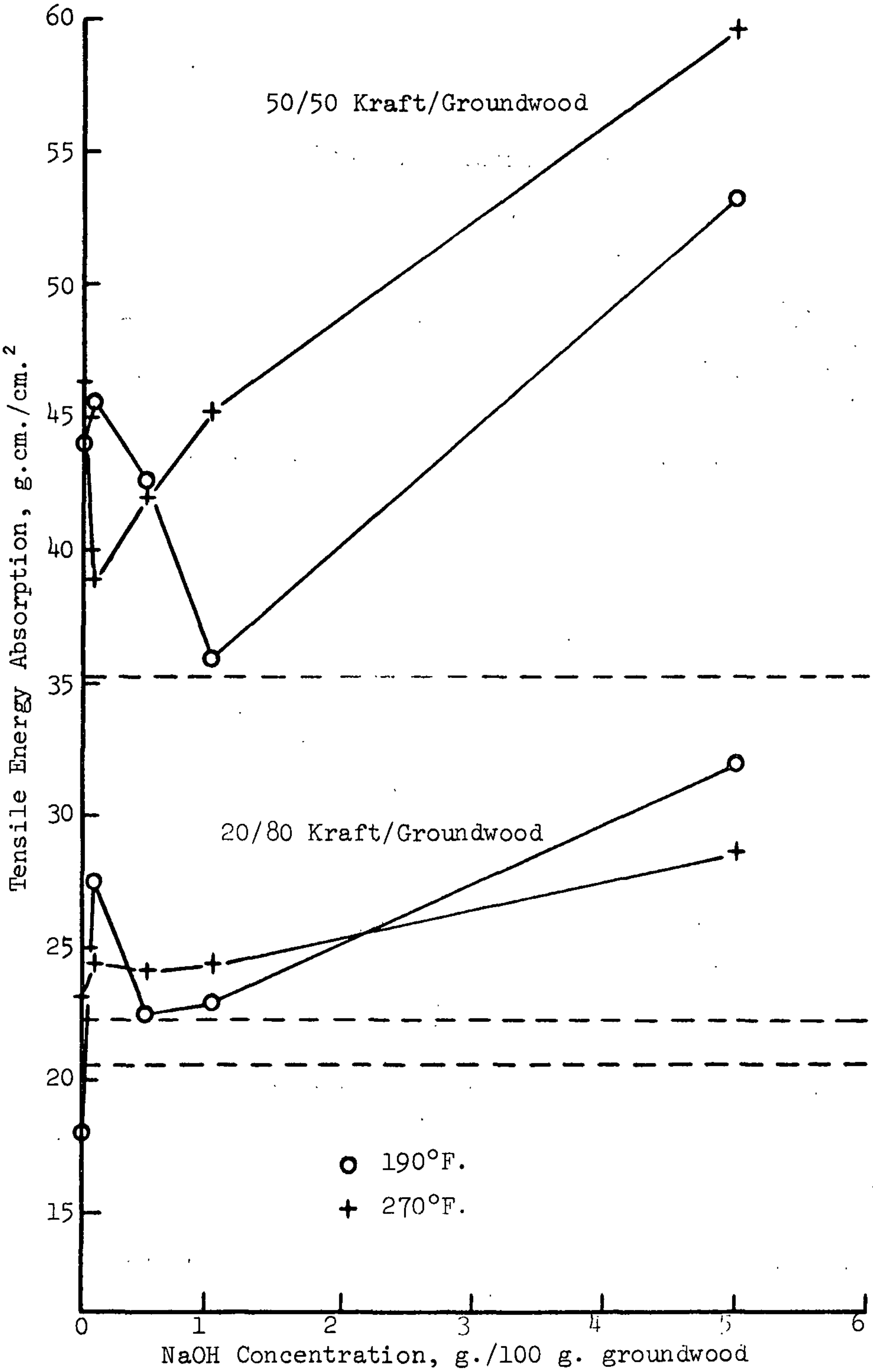

Figure 15. Tensile Energy Absorption vs. Alkali Concentration. The Broken Lines Indicate the Values Obtained with Untreated and Unheated Groundwood

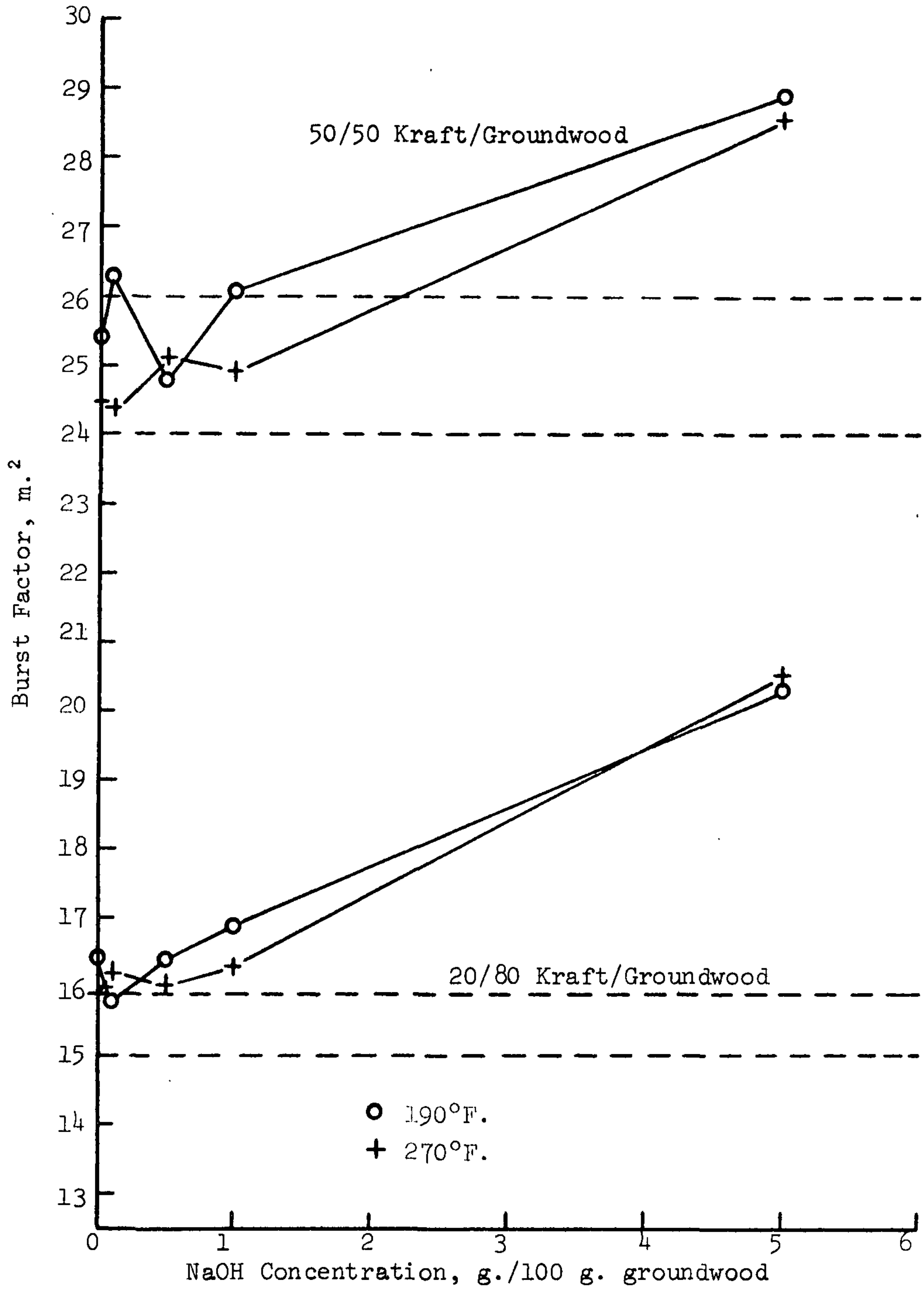

Figure 16. Burst Factor vs. Alkali Concentration. The Broken Lines Indicate the Values Obtained with Untreated and Unheated Groundwood

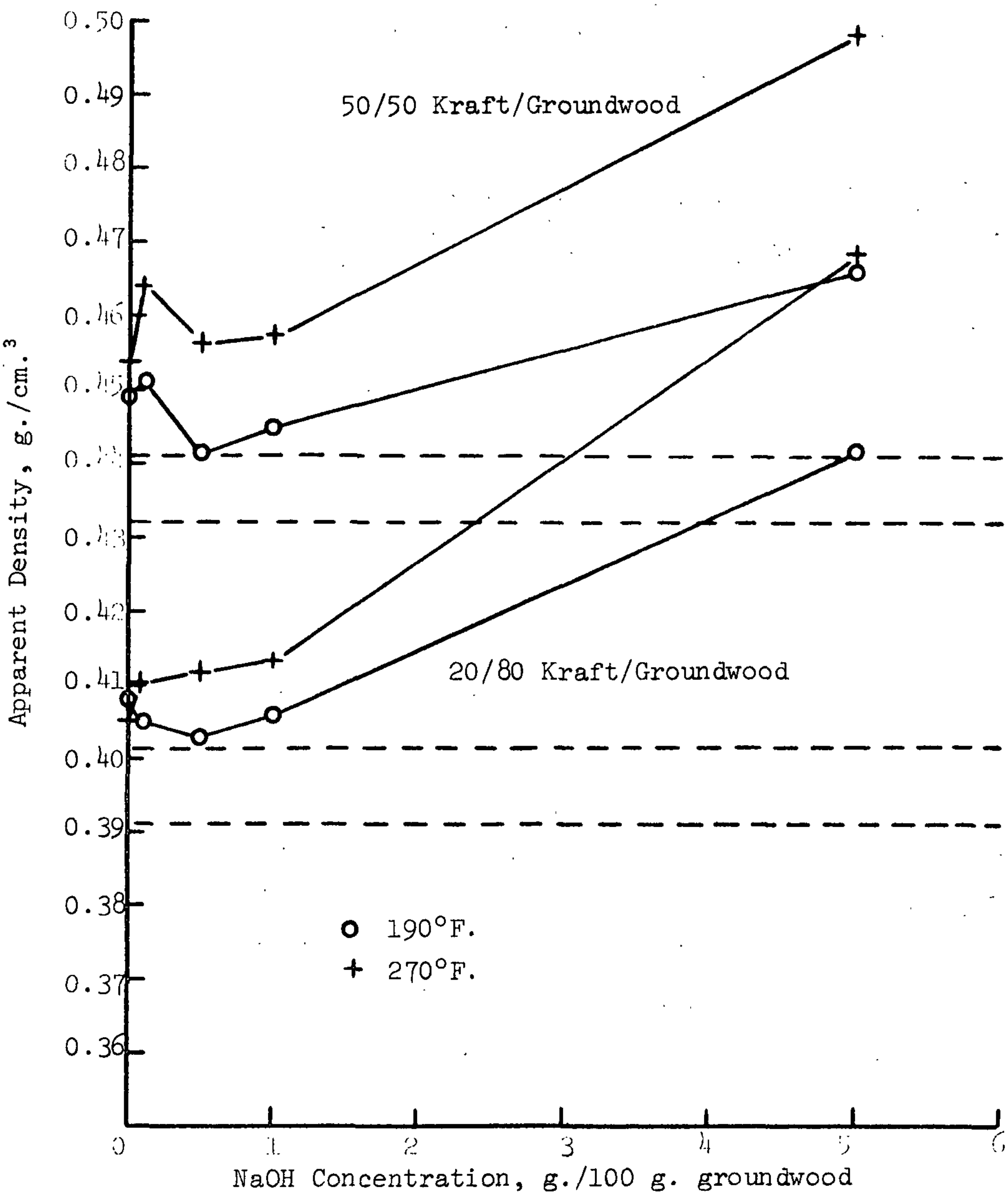

Figure 17. Apparent Density vs. Alkali Concentration. The Broken Lines Indicate the Values Obtained with Untreated and Unheated Groundwood

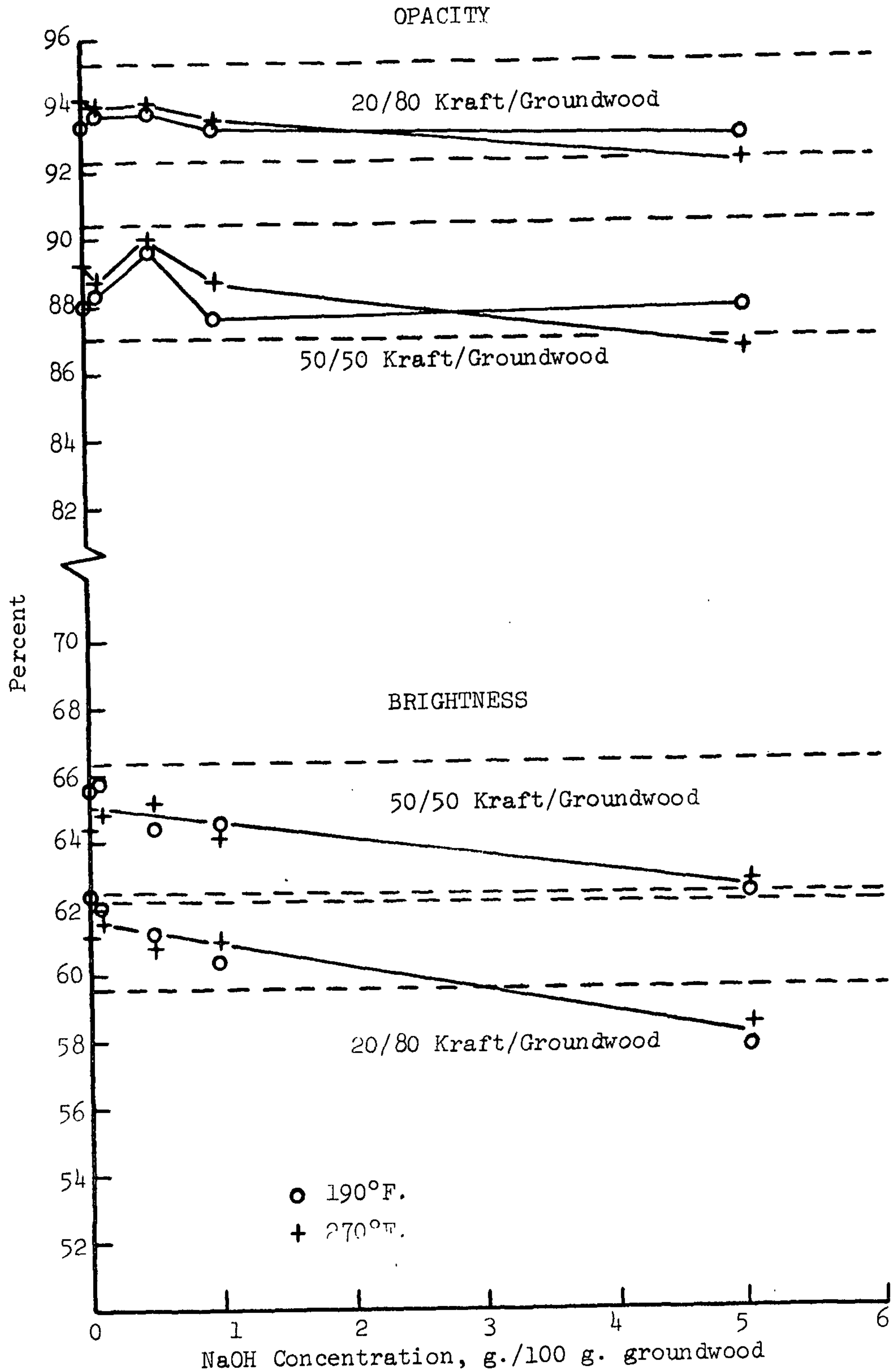

Figure 18. Optical Properties vs. Alkali Concentration. The Broken Lines Indicate the Values Obtained with Untreated and Unheated Groundwood

The data given in Table IX, were obtained from handsheets using groundwood jet cooked at 230°F. with 0, 5, and 10% NaOH and with 0 and 5% hydrogen peroxide. The primary objective was to see if the brightness loss due to the alkali could be avoided. But in addition, the effect of a processing temperature between 190 and 270°F. needed to be examined as well as the response of the pulp to alkali concentrations greater than 5%. The controls for the brightness maintenance experiment thus are intended to supplement the data given in Table VIII.

In Fig. 19, the opacity of the 20/80 and 50/50 kraft/groundwood handsheets appears to decrease linearly with the alkali concentration. Over the wider range of 0 to 10% NaOH (see Fig. 18) the loss is about 4 to 5 points for both blends, with and without 5% peroxide. The peroxide-treated groundwood handsheets do have lower opacity as expected with their higher brightness. Adding 5% peroxide to the pulp suspensions increases the handsheet brightness about 4 points without NaOH and with 5% NaOH by 9 points with the 50/50 and about 10 points with the 20/80 kraft/groundwood furnishes. The spread between the brightness values for the 5% NaOH treatment is even greater. Here the peroxide has increased the level by 13 points over the alkali controls.

The handsheet brightness of the 10% NaOH-treated groundwood blends is not different than the 5% NaOH samples from the 20/80 mixture but is reduced about 3 points for the 50/50 combination. However, the spread between the control and the peroxide treatments in 10% NaOH is about 12 points indicating that the effectiveness of the bleach has not been lost. It is not understood why the difference between the bleached and unbleached pulps actually increases when the same pulp preparation is used in the 20/80 blend. Here the bleached brightness is some 18 points greater than the alkali control. Possibly the

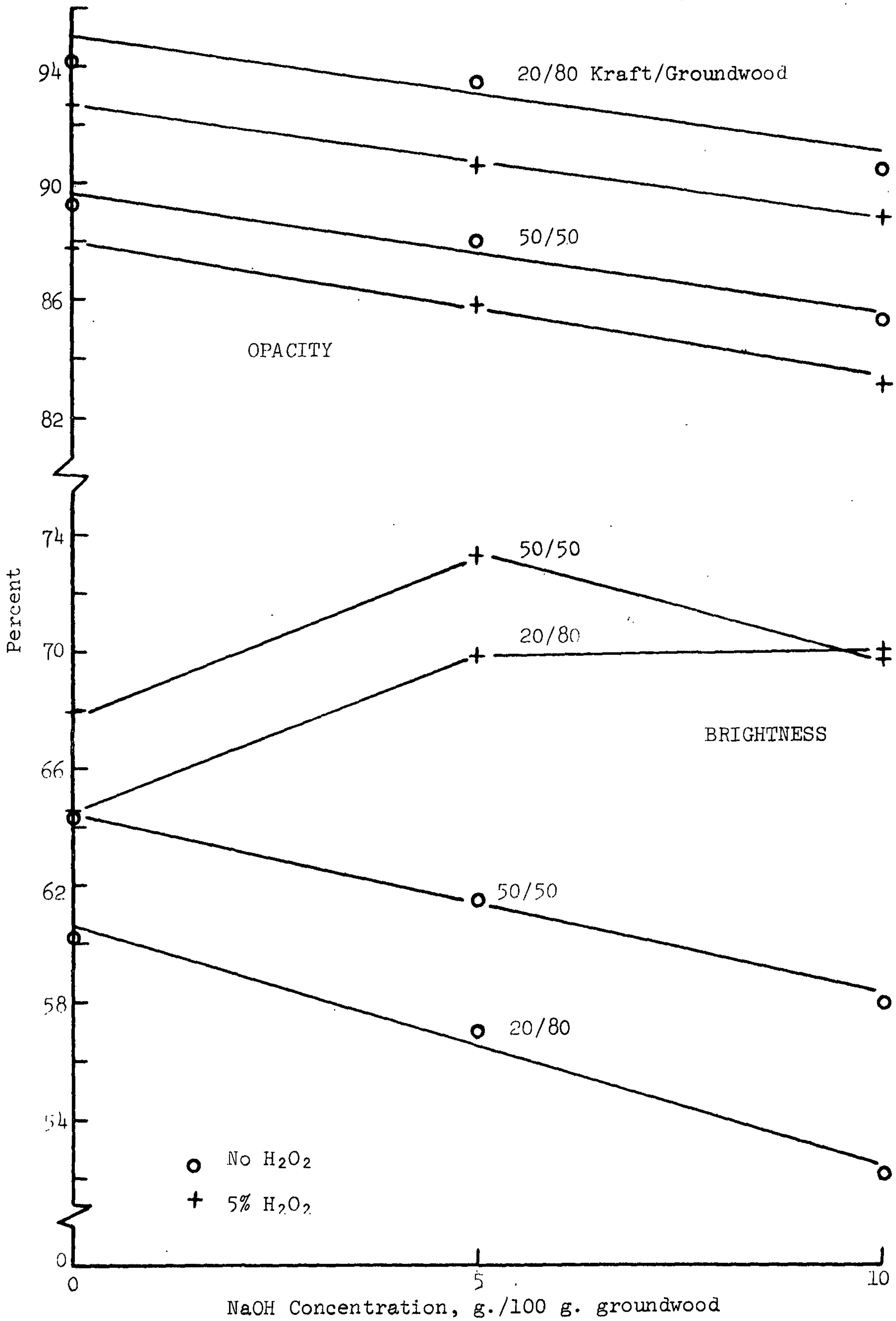

Figure 19. Optical Properties of Handsheets Treated in Alkali and Hydrogen Peroxide at 230°F.

greater difference is due to the lower level of bleached kraft pulp having less effect upon the sheet brightness.

The effect of adding 5% hydrogen peroxide on the weight of the dry pulp to the groundwood slurries jet cooked at 230°F. is to bleach the pulp more than is necessary to compensate for the darkening due to the use of 5 and 10% NaOH to strengthen the pulp. The short exposure of the pulp to the 230°F. processing temperature (discussed in the section describing the jet cooker) suggests most of the bleaching effect occurred in the cooker itself. If so, then it should be possible to bleach groundwood continuously within the lines conducting it from one stage to another within the pulp mill. If placed between the grinder pit and the screens, several steps in groundwood processing might be omitted.

Higher NaOH Concentration

Doubling the alkali concentration in the groundwood slurry from 5 to 10% appears to change the handsheet properties about as much as by going from 0 to 5%. The breaking length increases linearly, in Fig. 20, over the range of 0 to 10% NaOH. The presence of 5% hydrogen peroxide tends to reduce the breaking length of the handsheets — possibly by reducing the amount of available alkali. The before and after cooking pH values shown in Table IX are lower for those preparations using peroxide. Lower responses are to be seen in most of the data in Table IX for the peroxide treatments.

Bursting strength, tensile energy absorption, and apparent density are all elevated by the higher level of caustic in about the same manner as the breaking length. The tear factor is changed very little. The porosity of the handsheets, as measured by the Bendtsen air permeation rate, decreases with increasing amounts of NaOH as does the freeness of the mixed stock furnishes. In

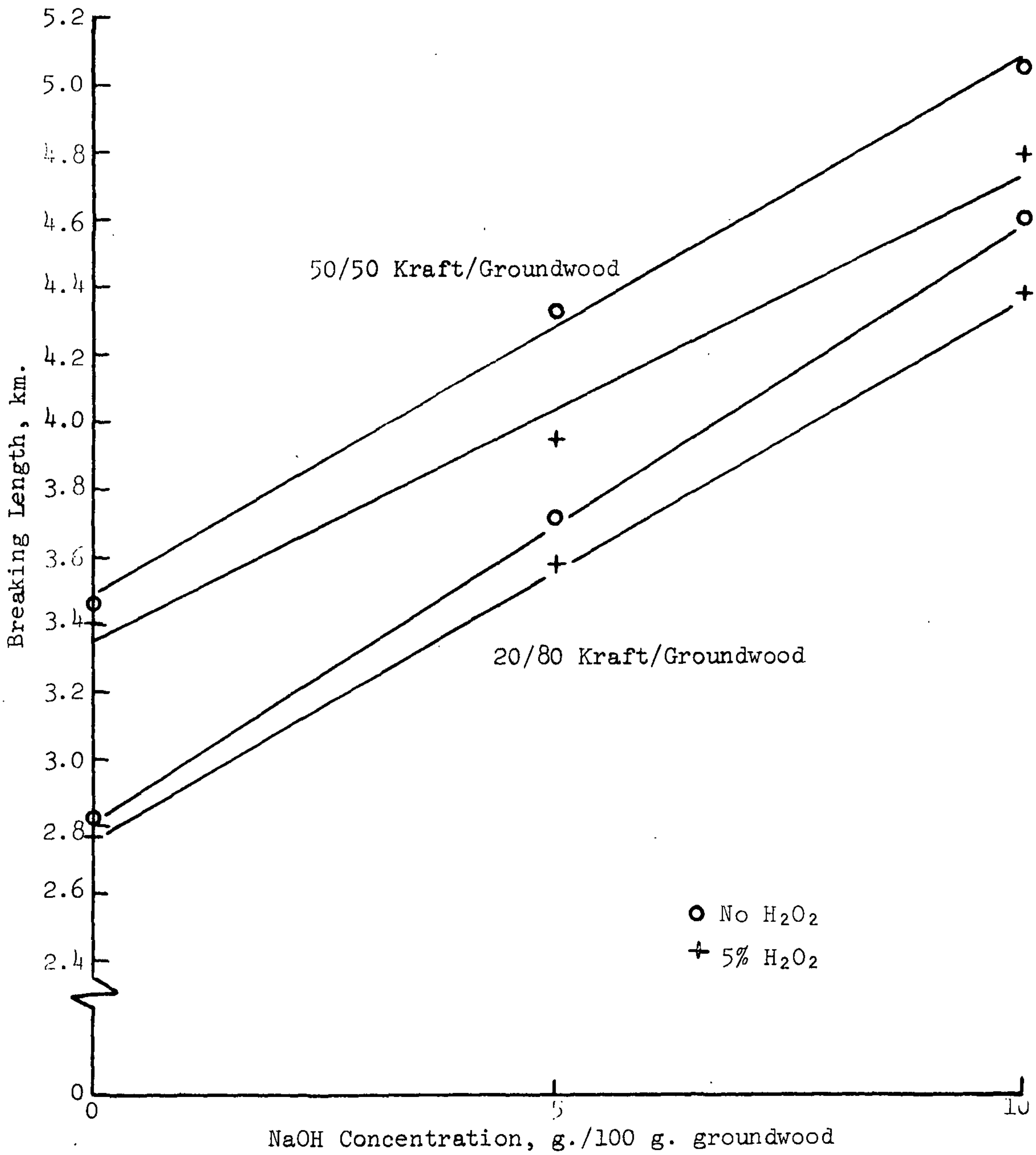

Figure 20. Tensile Strength of Handsheets Treated with Alkali and Peroxide at 230°F.

Fig. 21, Canadian freeness values for all the jet-cooked, alkali-treated pulps in Tables VIII and IX are plotted against the NaOH concentration. The freeness levels from the groundwood dispersed in the British disintegrator are indicated by broken lines for reference. Here, each blend is seen to decrease linearly with increasing amounts of NaOH.

The effect of the kind and concentration of fines upon porosity and freeness was discussed earlier and illustrated in Fig. 7 and 8. In view of these relationships, the trends noted for the pulps processed in the jet cooker with NaOH are consistent with two interpretations. The treatments are either producing significant amounts of fines or are making the groundwood fines more like kraft fines. Both are possible but the latter seems more likely.

Further experiments with NaOH treatments greater than 10% are indicated to determine the point at which no further improvements are obtained.

Effect of Temperature on Alkali Processing

As noted earlier, data from the 5% NaOH treatments in Tables VIII and IX are plotted in Fig. 11 and 12 along with the untreated, unheated groundwood controls given in Table VII. These figures give an overall view of the effects of jet cooking and jet cooking with 5% NaOH with respect to no treatment at all. In Fig. 11, the breaking length obtained with 5% NaOH reaches a maximum value with the 230°F. processing temperature. Both furnishes show the same trend. In Fig. 12, the tensile energy absorption increases with the processing temperature in the 50/50 furnish and decreases with the temperature for the 20/80 kraft/groundwood blend. The differences in the latter case are small, as are those between the 230° and 270°F. data. These relationships indicate the optimum processing temperature is near 230°F.

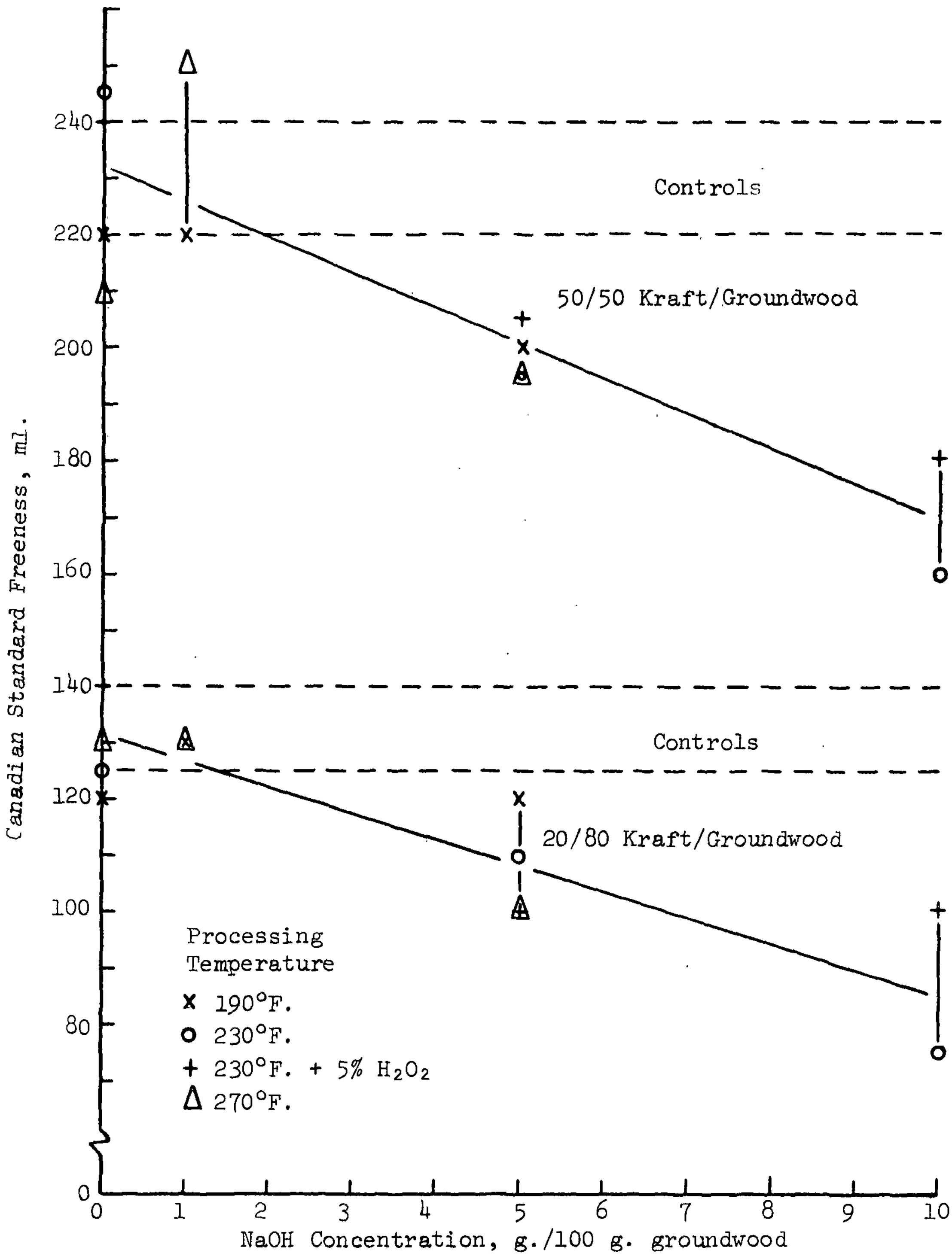

Figure 21. Freeness vs. Alkali Concentration. The Broken Lines Indicate the Values Obtained with Untreated and Unheated Groundwood

Summary of Jet Processing

It is shown that it is possible simultaneously to bleach and to improve bonding of a hardwood stone groundwood pulp in a rapid, continuous, in-line process. The economic feasibility has not been examined up to this point. Other workers have reported on the value of treating groundwoods with alkalies, bleaches, and heat, to improve to some degree the bonding ability of this class of pulps (12,17-21). However, the process concept described in this report differs from these earlier records in that higher processing temperatures are desired rather than to be avoided, and that bleaching and strength enhancement was accomplished simultaneously and continuously in a very much shorter time.

Jet cookers are being used at the present time to heat pulp slurries to processing temperatures at the paper machine and during the transfer of pulp to bleaching towers (26). Consequently, the basic design features which would be required to commercialize the concepts developed here have probably been fairly well developed.

CONCLUSIONS

The results of the program described in this report have shown that both the fine and coarse fractions of groundwood could benefit from treatments leading to enhanced plasticity and conformability for improved bonding. Therefore, chemical derivatization to achieve these ends is a reasonable approach even if the major effect is likely to be upon the fine fraction. It was found that xanthation and cross-linking to the xanthide form did produce groundwood handsheets having significantly improved strength properties. However, it was also observed that the alkaline treatment needed to bring about xanthation in itself produced even stronger handsheets. Heat processing in a continuous stream injection unit produced improvements in tensile strength of the order of 8 to 10% while 10% NaOH plus heat processing at 230°F. produced values 75% higher than the controls in 20/80 kraft/groundwood blends. Darkening of the pulp due to the alkali was more than compensated by the further addition of 5% hydrogen peroxide. A significant bleaching effect was observed indicating the technical feasibility of proposing continuous in-line bleaching in conjunction with bonding improvement for the aspen stone groundwood used in this study.

FUTURE WORK

There are a number of factors which need to be examined but those which appear to have the most significance at this time are:

1. Responsiveness of other kinds of groundwood.
2. Processing losses due to extraction.
3. Residual alkali to be recycled.
4. Minimum levels of peroxide needed to restore brightness.
5. Response of bleaching to processing temperature.

These topics are currently under investigation and will be evaluated in a subsequent report.

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